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13. ABSTRACT *(Maximum 200 words)*
This Final Feasibility Report/Environmental Impact Statement (RE/EIS) and its 21 appendices document the results of a comprehensive analysis of the four dams on the lower Snake River (collectively called the Lower Snake River Project) and their effects on four lower Snake River salmon and steelhead stocks listed for protection under the Endangered Species Act (ESA). The U.S. Army Corps of Engineers (Corps), along with Bonneville Power Agency (BPA), U. S. Environmental Protection Agency (EPA), and U. S. Bureau of Reclamation (BOR) as cooperating agencies, analyzed four alternatives to evaluate the best way to improve juvenile salmon migration through Lower Snake River Project. The Final FR/EIS includes the best available information on the biological effectiveness, engineering components, costs, economic effects, and other environmental effects associated with the four alternatives: Alternative 1-Existing Conditions, Alternative 2-Maximum Transport of Juvenile Salmon, Alternative 3-Major System Improvements (Adaptive Migration), and Alternative 4-Dam Breaching. In the Final FR/EIS, the Corps identifies Alternative 3-Major System Improvements (Adaptive Migration) as the recommended plan (preferred alternative) and explains the process for selecting that alternative.

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FEASIBILITY STUDY DOCUMENTATION

	Document Title
Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement	
Appendix A (bound with B)	Anadromous Fish Modeling
Appendix B (bound with A)	Resident Fish
Appendix C	Water Quality
Appendix D	Natural River Drawdown Engineering
Appendix E	Existing Systems and Major System Improvements Engineering
Appendix F (bound with G, H)	Hydrology/Hydraulics and Sedimentation
Appendix G (bound with F, H)	Hydroregulations
Appendix H (bound with F, G)	Fluvial Geomorphology
Appendix I	Economics
Appendix J	Plan Formulation
Appendix K	Real Estate
Appendix L (bound with M)	Lower Snake River Mitigation History and Status
Appendix M (bound with L)	Fish and Wildlife Coordination Act Report
Appendix N (bound with O, P)	Cultural Resources
Appendix O (bound with N, P)	Public Outreach Program
Appendix P (bound with N, O)	Air Quality
Appendix Q (bound with R, T)	Tribal Consultation and Coordination
Appendix R (bound with Q, T)	Historical Perspectives
Appendix S*	Snake River Maps
Appendix T (bound with R, Q)	Clean Water Act, Section 404(b)(1) Evaluation
Appendix U	Response to Public Comments

*Appendix S, Lower Snake River Maps, is bound separately (out of order) to accommodate a special 11 x 17 format.

The documents listed above, as well as supporting technical reports and other study information, are available on our website at http://www.nww.usace.army.mil/lsr. Copies of these documents are also available for public review at various city, county, and regional libraries.

AQM03-06-1247

STUDY OVERVIEW

Purpose and Need

Between 1991 and 1997, due to declines in abundance, the National Marine Fisheries Service (NMFS) made the following listings of Snake River salmon or steelhead under the Endangered Species Act (ESA) as amended:

- sockeye salmon (listed as endangered in 1991)
- spring/summer chinook salmon (listed as threatened in 1992)
- fall chinook salmon (listed as threatened in 1992)
- steelhead (listed as threatened in 1997).

In 1995, NMFS issued a Biological Opinion on operations of the Federal Columbia River Power System (FCRPS). Additional opinions were issued in 1998 and 2000. The Biological Opinions established measures to halt and reverse the declines of ESA-listed species. This created the need to evaluate the feasibility, design, and engineering work for these measures.

The Corps implemented a study (after NMFS' Biological Opinion in 1995) of alternatives associated with lower Snake River dams and reservoirs. This study was named the Lower Snake River Juvenile Salmon Migration Feasibility Study (Feasibility Study). The specific purpose and need of the Feasibility Study is to evaluate and screen structural alternatives that may increase survival of juvenile anadromous fish through the Lower Snake River Project (which includes the four lowermost dams operated by the Corps on the Snake River—Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Dams) and assist in their recovery.

Development of Alternatives

The Corps' response to the 1995 Biological Opinion and, ultimately, this Feasibility Study, evolved from a System Configuration Study (SCS) initiated in 1991. The SCS was undertaken to evaluate the technical, environmental, and economic effects of potential modifications to the configuration of Federal dams and reservoirs on the Snake and Columbia Rivers to improve survival rates for anadromous salmonids.

The SCS was conducted in two phases. Phase I was completed in June 1995. This phase was a reconnaissance-level assessment of multiple concepts including drawdown, upstream collection, additional reservoir storage, migratory canal, and other alternatives for improving conditions for anadromous salmonid migration.

The Corps completed a Phase II interim report on the Feasibility Study in December 1996. The report evaluated the feasibility of drawdown to natural river levels, spillway crest, and other improvements to existing fish passage facilities.

Based in part on a screening of actions conducted for the Phase I report and the Phase II interim report, the study now focuses on four courses of action:

- Existing Conditions
- Maximum Transport of Juvenile Salmon

- Major System Improvements
- Dam Breaching.

The results of these evaluations are presented in the combined Feasibility Report (FR) and Environmental Impact Statement (EIS). The FR/EIS provides the support for recommendations that will be made regarding decisions on future actions on the Lower Snake River Project for passage of juvenile salmonids. This appendix is a part of the FR/EIS.

Geographic Scope

The geographic area covered by the FR/EIS generally encompasses the 140-mile long lower Snake River reach between Lewiston, Idaho and the Tri-Cities in Washington. The study area does slightly vary by resource area in the FR/EIS because the affected resources have widely varying spatial characteristics throughout the lower Snake River system. For example, socioeconomic effects of a permanent drawdown could be felt throughout the whole Columbia River Basin region with the most effects taking place in the counties of southwest Washington. In contrast, effects on vegetation along the reservoirs would be confined to much smaller areas.

Identification of Alternatives

Since 1995, numerous alternatives have been identified and evaluated. Over time, the alternatives have been assigned numbers and letters that serve as unique identifiers. However, different study groups have sometimes used slightly different numbering or lettering schemes and this has led to some confusion when viewing all the work products prepared during this long period. The primary alternatives that are carried forward in the FR/EIS currently involve the following four major courses of action:

Alternative Name	PATH[1/] Number	Corps Number	FR/EIS Number
Existing Conditions	A-1	A-1	1
Maximum Transport of Juvenile Salmon	A-2	A-2a	2
Major System Improvements	A-2'	A-2d	3
Dam Breaching	A-3	A-3a	4

[1/] Plan for Analyzing and Testing Hypotheses

Summary of Alternatives

The **Existing Conditions Alternative** consists of continuing the fish passage facilities and project operations that were in place or under development at the time this Feasibility Study was initiated. The existing programs and plans underway would continue unless modified through future actions. Project operations include fish hatcheries and Habitat Management Units (HMUs) under the Lower Snake River Fish and Wildlife Compensation Plan (Comp Plan), recreation facilities, power generation, navigation, and irrigation. Adult and juvenile fish passage facilities would continue to operate.

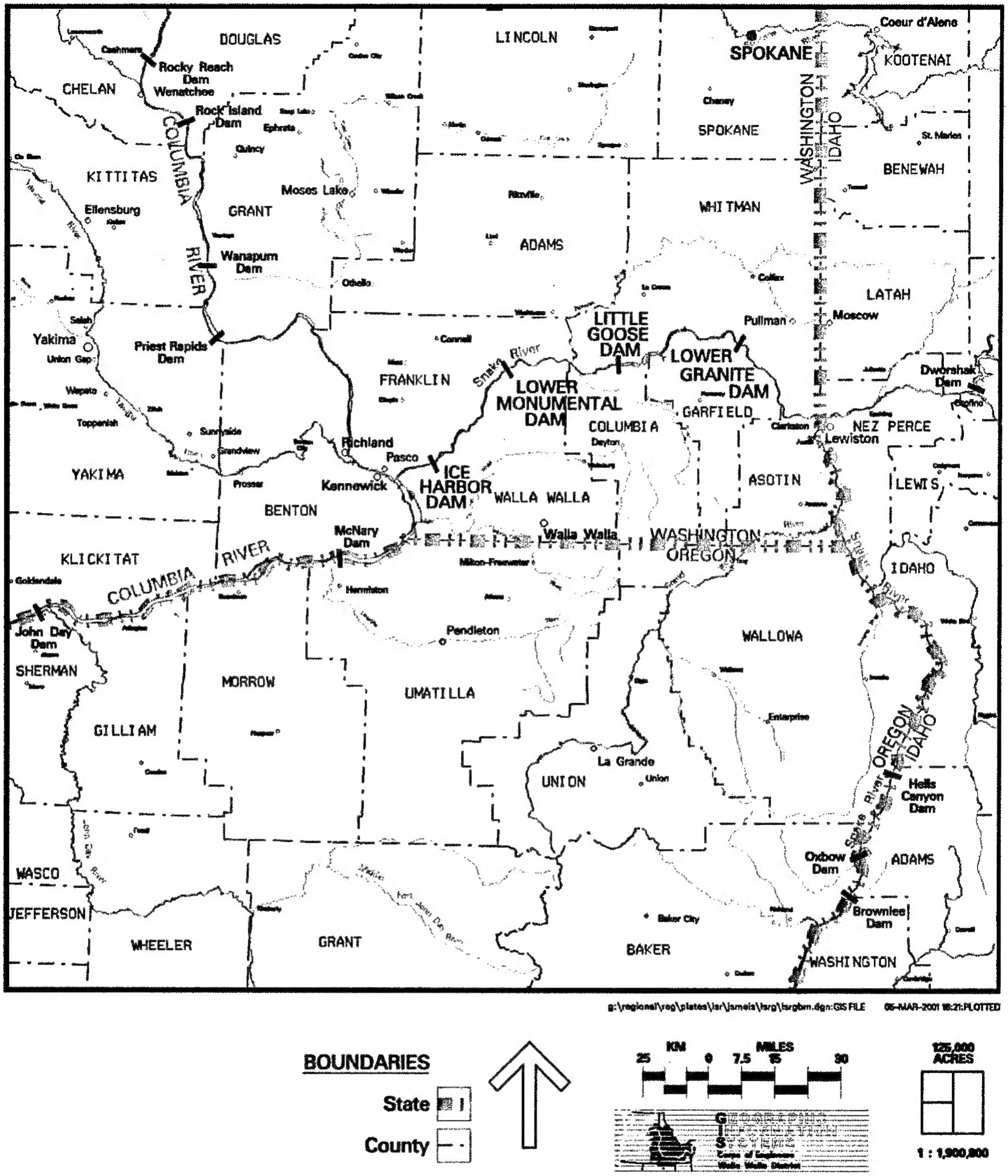
The **Maximum Transport of Juvenile Salmon Alternative** would include all of the existing or planned structural and operational configurations from the Existing Conditions Alternative. However, this alternative assumes that the juvenile fishway systems would be operated to maximize fish transport from Lower Granite, Little Goose, and Lower Monumental and that voluntary spill would not be used to bypass fish through the spillways (except at Ice Harbor). To accommodate this maximization of transport, some measures would be taken to upgrade and improve fish handling facilities.

The **Major System Improvements Alternative** would provide additional improvements to what is considered under the Existing Conditions Alternative. These improvements would be focused on using surface bypass facilities such as surface bypass collectors (SBCs) and removable spillway weirs (RSWs) in conjunction with extended submerged bar screens (ESBSs) and a behavioral guidance structure (BGS). The intent of these facilities would be to provide more effective diversion of juvenile fish away from the turbines. Under this alternative, an adaptive migration strategy would allow flexibility for either in-river migration or collection and transport of juvenile salmon downstream in barges and trucks.

The **Dam Breaching Alternative** has been referred to as the "Drawdown Alternative" in many of the study groups since late 1996 and the resulting FR/EIS reports. These two terms essentially refer to the same set of actions. Because the term drawdown can refer to many types of drawdown, the term dam breaching was created to describe the action behind the alternative. The Dam Breaching Alternative would involve significant structural modifications at the four lower Snake River dams, allowing the reservoirs to be drained and resulting in a free-flowing yet controlled river. Dam breaching would involve removing the earthen embankment sections of the four dams and then developing a channel around the powerhouses, spillways, and navigation locks. With dam breaching, the navigation locks would no longer be operational and navigation for large commercial vessels would be eliminated. Some recreation facilities would close while others would be modified and new facilities could be built in the future. The operation and maintenance of fish hatcheries and HMUs would also change, although the extent of change would probably be small and is not known at this time.

Authority

The four Corps dams of the lower Snake River were constructed and are operated and maintained under laws that may be grouped into three categories: 1) laws initially authorizing construction of the project, 2) laws specific to the project passed subsequent to construction, and 3) laws that generally apply to all Corps reservoirs.



LOWER SNAKE RIVER
Juvenile Salmon Migration Feasibility Study

REGIONAL BASE MAP

US Army Corps
of Engineers®
Walla Walla District

Final

Lower Snake River Juvenile Salmon Migration Feasibility Report/ Environmental Impact Statement

Appendix N

Cultural Resources

February 2002

US Army Corps
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Final
Lower Snake River Juvenile Salmon Migration Feasibility Report/ Environmental Impact Statement

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Appendix N
Cultural Resources

Produced by

U.S. Army Corps of Engineers
Walla Walla District

February 2002

FOREWORD

Appendix N was prepared by the U.S. Army Corps of Engineers (Corps), Walla Walla District. This appendix is one part of the overall effort of the Corps to prepare the Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement (FR/EIS).

The Corps has reached out to regional stakeholders (Federal agencies, tribes, states, local governmental entities, organizations, and individuals) during the development of the FR/EIS and appendices. This effort resulted in many of these regional stakeholders providing input and comments, and even drafting work products or portions of these documents. This regional input provided the Corps with an insight and perspective not found in previous processes. A great deal of this information was subsequently included in the FR/EIS and appendices; therefore, not all of the opinions and/or findings herein may reflect the official policy or position of the Corps.

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FIGURES

ACRONYMS AND ABBREVIATIONS

AIRFA	American Indian Religious Freedom Act
APE	area of potential effects
ARPA	Archaeological Resources Protection Act
BP	before present
CFR	Code of Federal Regulations
Corps	U.S. Army Corps of Engineers
CRM	Cultural Resource Management
EIS	Environmental Impact Statement
FR/EIS	Lower Snake River Juvenile Salmon Migration Feasibility Report/ Environmental Impact Statement
LSRP	Lower Snake River Project
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NRHP	National Register of Historic Places

ENGLISH TO METRIC CONVERSION FACTORS

To Convert From	To	Multiply By
LENGTH CONVERSIONS:		
Inches	Millimeters	25.4
Feet	Meters	0.3048
Miles	Kilometers	1.6093
AREA CONVERSIONS:		
Acres	Hectares	0.4047
Acres	Square meters	4047
Square Miles	Square kilometers	2.590
VOLUME CONVERSIONS:		
Gallons	Cubic meters	0.003785
Cubic yards	Cubic meters	0.7646
Acre-feet	Hectare-meters	0.1234
Acre-feet	Cubic meters	1234
OTHER CONVERSIONS:		
Feet/mile	Meters/kilometer	0.1894
Tons	Kilograms	907.2
Tons/square mile	Kilograms/square kilometer	350.2703
Cubic feet/second	Cubic meters/sec	0.02832
Degrees Fahrenheit	Degrees Celsius	(Deg F –32) x (5/9)

Executive Summary

The Cultural Resources Appendix of the Lower Snake River Juvenile Salmon Migration Feasibility Study addresses effects to cultural resources that may be caused by the proposals under consideration.

The Corps manages lands in the lower Snake River that lie within the southern Columbia Plateau Culture Area. This is a distinct region with a rich archaeological past and a part of a culturally significant present for both Native and Euro-Americans. Archaeological data indicate that people have been living in the region for at least 11,000 years. Much human activity has taken place along the river in areas now managed by the Corps and where proposed management actions are being considered in the current Feasibility Study.

Federal agencies are required by Federal law to preserve, protect, and manage cultural resources such as archaeological sites, historical sites, sacred sites, and traditional cultural properties. In order to meet this responsibility, the Corps is studying the nature of the cultural resources which may be impacted by the project alternatives and how the impacts can be avoided, minimized, or mitigated. Since impacts to cultural resources will be only moderately changed by the first three FR/EIS alternatives, this appendix focuses on Alternative 4—Dam Breaching. This alternative would significantly change the nature of cultural resources impacts and the necessary management actions.

Dam breaching would expose cultural sites that have been under water for many years. Vegetation, soil cover, soil stability, and other factors will have changed greatly at the re-exposed sites because of long-term inundation. Increased access to the re-exposed sites and future potential uses of the land would also have to be considered. Given that only a few comprehensive inventories have ever been conducted for reservoir lands, even for those currently accessible, fundamental unknowns exist that limit an analysis of how cultural resources would respond to either continued decades of inundation or the effects of re-exposure. The uncertainties for cultural resources (i.e., exact circumstances of their locations and conditions and what reasonable remedies are actually available to address adverse impacts to them) are impediments to any quantifiable assessments of cultural resources effects under the Dam Breaching alternative. However, monitoring of accessible resources and studies of inundated archaeological sites found under analogous conditions elsewhere suggest continued inundation of cultural resources is less preferable than effects resulting from reservoir drawdowns (Center for Northwest Anthropology, 1992). Direct access and management treatments for all Corps cultural resources are considered likely benefits that would generally reduce losses in cultural resources' integrity and more fully enable the Corps to consider them under existing Federal laws.

Cultural resources program objectives will be to meet current Federal laws and agency policies under whatever alternative is chosen for the Final Environmental Impact Statement (EIS) and Record of Decision. This includes consultation and collaboratively involving affected Indian tribes and traditional communities in Corps cultural resources planning and management activities. Concerns and remedies for cultural resources emerging from changed environmental conditions will be addressed through a host of program strategies including the following: Cultural Resources education/interpretation, enforcement of Federal cultural resources protection laws, comprehensive resource inventories, monitoring activities, site evaluations and nominations to the National Register

of Historic Places (NHRP), and mitigation approaches such as data recovery to help preserve significant historic property values.

Under the Dam Breaching alternative many of the above management strategies must be rapidly implemented in order to limit adverse impacts to lower Snake River cultural resources. Systematic site evaluations must follow site exposures to determine the effects of years of inundation and appropriate treatments for groups of sites in order to protect or salvage the cultural and scientific values. Cultural resources management program actions necessarily would be a part of an ongoing process that would continue years after the implementation of a Feasibility Study alternative.

1. Introduction

In order to increase anadromous fish survival, this study is considering alternative actions, some of which would greatly change the management of the lower Snake River facilities. Cultural resources along the river would be affected by the implementation of any of the alternatives. Federal agencies must comply with numerous laws, regulations, policies, and directives while considering change in water or land management. The Walla Walla District, U.S. Army Corps of Engineers (Corps) is the Federal agency responsible for the preservation and management of cultural resources within the lower Snake River project.

Much of this appendix has been taken from earlier cultural resources management documents produced by Federal agencies in the Columbia River Basin. This includes *An Overview of Cultural Resources in the Snake River Basin* by Kenneth C. Reid and others, *The Walla Walla District Cultural Resources Management Plan,* and the *Columbia River System Operation Review Final Environmental Impact Statement Cultural Resources Appendix*, as well as other documents. Although much information appearing here was penned in support of other undertakings, the nature of cultural resource management in the region is such that text presented here from earlier sources is considered valid for the present study.

Feasibility Study alternatives related to cultural resources are summarized as follows:

- Under Alternative 1—Existing Systems, the hydropower facilities would continue to operate as originally designed, and reservoir fluctuations would not change. For the most part, geomorphic processes have reached a near-equilibrium under operations since the impoundment of the reservoirs. However, reservoir adjustments to optimize hydropower production, commercial navigation, irrigation, and recreation have caused numerous impacts. Ongoing erosion has stabilized to some extent on the reservoirs. Some of this effect is due to bank stabilization structures in place at various locations, which are designed to slow or halt erosion.
- Under Alternative 2—Maximized Transport of Juvenile Salmon and Alternative 3—Major System Improvements, current conditions (as described above) would continue.
- Under Alternative 4—Dam Breaching, the lower Snake River would be unimpounded from Hells Canyon Dam to the confluence of the Snake River with the Columbia River, with some seasonal flow augmentation intended to support anadromous fish runs. This would expose sites that have been inundated for up to 40 years. Some existing bank stabilization measures could be made superfluous by the dam breaching alternative. Many, however, would still provide a level of protection from impacts other than those for which they were originally designed.

1.1 Purposes and Objectives

As a part of the Corps' compliance requirements under Sections 106 and 110 of the National Historic Preservation Act of 1966 (NHPA), this document provides an assessment of the cultural resources environment as now understood with regard to the current study. Proposed actions under this study would impact cultural and historic properties in a number of potential ways. Those impacts must be understood, provided for, and mitigated to the extent practicable for each of the alternative pathways.

1.2 Cultural Resources Defined

While the term "cultural resources" can encompass a wide array of terms, for purposes of this study it will be limited to the definition provided in the NHPA, Title III, Section 301 (5). As defined in this section, "historic property" or "historic resource" means any prehistoric or historic district, site, building, structure, or object included in, or eligible for inclusion on the National Register, including artifacts, records, and material remains related to such a property or resource. Cultural resources in the Snake River Basin consist of artifacts, sites, and districts (groups of closely associated sites). Together these resources represent the full range of prehistory and history (over 11,000 years of human presence) by indigenous cultures, and historic American settlement in the lower Snake River, and traditional cultural properties. Typically, traditional cultural properties require the involvement of a specific cultural group (American Indian communities/tribes) in order to be identified and documented. Cultural resources also include the remains of historic settlement and development activities of Euro-Americans, Asians, and other non-Native cultural activities over the past 200 years.

Prehistoric period archaeological sites are typically represented by open campsites, housepit villages, rock shelters, rock art (petroglyphs/pictographs), lithic quarries and workshops, burials and cemeteries; and isolated rock cairns, pits, and alignments. Historical sites are denoted by structures, buildings, and objects that represent post-contact Euro-American activity. These include the remains of farms, towns, trading posts, mining sites, military forts, burial sites, abandoned settlements, and transportation and industrial facilities. These features are identified and evaluated on the basis of tangible traces, materials, or scientific evidence of significant cultural activity.

Contemporary Native Americans recognize archaeological sites, but also emphasize their interests in traditional cultural properties. Traditional cultural properties, as a class of cultural resources, may include a broad range of features from the natural environment and the sacred world. For example, certain distinctive shapes in the natural landscape, features in a tribe's cultural geography, habitats for culturally significant food and medicinal plants, traditional fisheries, sacred religious sites, and places of spiritual renewal may comprise traditional cultural properties. Some tribes assert that the Snake River itself is a traditional cultural property. Traditional cultural properties are places and resources comprised of both cultural sites and natural elements significant in contemporary traditional social and religious practices, which often help preserve traditional cultural identities of an ethnic group.

The cultural resources of the lower Snake River are a rich source of information about past human activity and are directly subject to impacts by the water resources developments. The record of human activity in the Snake River Basin, as revealed in archaeological and historical studies, may go back 13,000 years and possess valuable information about the environment and human adaptation to it over time. As the cultural resources of the region become more fully known through systematic investigation and analysis, a better understanding of the past life ways of native peoples can be gained.

1.2.1 Criteria of Significance

The question is often posed: Are all old things equally important? How are heritage resources assessed for their significance? Cultural resources significance is a legal standard reached through an evaluation process as defined in 36 Code of Federal Regulations (CFR) Part 60 (NHPA). This process, involving identification and evaluation, is used to determine the eligibility status of cultural

resources for listing on the National Register of Historic Places (NRHP); it involves the identification, evaluation and management of cultural resources. In 36 CFR Part 60.4 (criteria for evaluation) it states that a property must possess the quality of significance in American history, architecture, archaeology, engineering, or culture; integrity of location, design, setting, materials, workmanship, feeling, and association; and

a) Be associated with events that have made a significant contribution to the broad patterns of our history; or

b) Be associated with the lives of persons significant in our past; or

c) Embody the distinctive characteristics of a type, period, or method of construction; or that represent the work of a master; or that possesses high artistic value or that represents a significant and distinguishable entity whose components may lack individual distinction; or

d) That have yielded, or may be likely to yield, information important in prehistory or history.

In addition, National Register Bulletin No. 38 from the National Park Service advises Federal agencies that traditional cultural properties with traditional cultural significance may be determined eligible for the NRHP. "Traditional" in this context refers to those beliefs, customs, and practices of a living community of people that have been passed down through the generations, usually orally or through practice.

Under Section 106 of the NHPA, Federal agencies are required to take into account the effects of their undertakings on all cultural resources included in, or eligible for, the NRHP (i.e., "significant" cultural resources). Agencies are also required to afford the Advisory Council on Historic Preservation a reasonable opportunity to comment on such undertakings. Included within the Section 106 process is the identification and evaluation (i.e., determination of significance) of cultural resources within the proposed project area and an assessment of potential project impacts on all significant properties. Within the Feasibility Study area of potential effects (APE) most of the cultural resource sites that have been identified have not been evaluated for eligibility for listing on the National Register. Completion of this process is the first necessary cultural resource management task for Federal agencies in addressing or taking into account project effects.

1.2.2 Historical Significance

Archaeological and historic sites are significant for a variety of different reasons based upon their NRHP eligibility and as defined by the Criteria of Evaluation described above. The Criteria of Eligibility for NRHP (described above) make special reference to the quality of preservation of sites and their contents, their location, the integrity of setting and materials, and their association with particular ethnic groups or historically known individuals and events. The particular site setting and/or contents may be essential in evaluating and applying research questions about the past. The level of significance varies according to the question asked and the potential of the site for providing relevant information.

Common research themes in regional archaeological investigations have been concerned with culture history (i.e., events in the history of a culture, particularly the sequence and age of those events); different aspects of culture process (i.e., how people in the past carried out certain kinds of activities); and human adaptations in response to environmental changes (i.e., association with natural events such as floods, volcanic eruptions, mud slides, climate changes, and forest fires).

Matters of scientific interest (e.g., paleontology, paleo-environmental reconstruction, and palynology), even if not directly associated with archaeological sites, are important as NEPA considerations.

Archaeological sites are also important to the heritage of regional Native American groups. However, their primary interest tends to lie not so much with scientific investigations as with protection and restoration of places/resources to the benefit of cultural uses, cultural identities, and values for community and family heritage. Archaeological sites are also of interest to the general public from the standpoint of aesthetics, history, science, or recreation. Finally, some sites are significant for their importance in the context of certain themes, patterns, or trends in American history.

1.2.3 The Scales of Cultural Resource Values

1.2.3.1 Large-scale Resource Values

Large-scale resource values are regional in scope. They include regional ecological patterns, geological conditions, cultural relationships, and cultural features. Reservoir construction and subsequent inundation of a significant reach of a river valley constitutes an important large-scale effect on the environmental context of the resource database. Replacement of the riverine and terrestrial environments with a reservoir system transforms these into a single lake-like environment. A significant body of information about the former ecosystems—including much of the cultural and geological data connected to these systems lying both inside and outside the direct impact zone of the reservoir—is lost during the transformation. For example, the relationships between inundated sites and those sites lying outside the reservoir are altered or possibly destroyed.

1.2.3.2 Medium-scale Values

Medium-scale values include local patterns of human use, vegetation assemblages, or geological features. This encompasses sites or places where there is evidence of human use, evidence of a particular array of vegetation types, or evidence of a geological process. A site is defined as an assemblage of objects and their relationships to one another and with other objects in the ecosystem. For instance, the archaeological context of a site is a set of ordered relationships that result from nonrandom output of human activities arrayed in the same time and space. Establishing a reservoir on a site can alter these relationships by changing the environmental context of the site through the acceleration of erosion. The long-term action of erosive waves and currents along the pool shoreline redistributes objects, altering their spatial context. If enough material is eroded away and objects are displaced from the strata in which they were originally deposited, their time context is also altered.

1.2.3.3 Small-scale Values

Small-scale values include the objects on a site, such as the artifacts (movable items manufactured by humans) and features (immovable manufactured items) of the site. Since analysis techniques rely on objects or their attributes, the concern is focused on the effects of reservoir processes on objects or artifact assemblages (groupings of associated artifacts) and attributes. Each object, artifact, and feature has a set of measurable characteristics and attributes, which carries some information about human behavior. An irretrievable effect of inundation on artifacts and features is the loss of information about human behavior such cultural remains can reveal. Other objects may be displaced; break apart; or changes in size and weight, shape, or chemical composition. However,

such small-scale effects are cumulative and tend to gain significance over time. An example is the initiation of soil mass movement that begins at the soil particle level as water within the soil pores flows away from high pressure areas to lower pressure areas during rapid lowering of a reservoir. As chain reactions result from this small-scale movement, slumping or mass movement develops down slope. This changes the character of the site as well as some attributes of the objects on the site.

1.2.4 Native Peoples: Cultural Resources—The Tribal Perspective

The significance of the lower Snake River and its resources to affected tribes and traditional communities is rich and complex. Palous, Walla Walla, Wanapum, and Nez Perce descendants still live in or near this river basin. Some learned their living heritage through participation in altered traditional season rounds and Indian religious and social customs within the context of lower Snake River environments. The hallowed graves of close and distant relatives are located along this portion of the Snake River Basin. These and other places spoken of in the ancient oral traditions are still recounted by some traditional people causing their significance to merge into people's modern lives. The Snake River is indeed much more than what it may appear to be or represent to resident non-Indian people (Trafzer and Scheuerman, 1986).

Because the tribal definition of cultural resources is much broader in scope than the NHPA definition used here, the reader's attention is directed to other technical appendices of the Feasibility Study, such as Resident Fish, Wildlife, Anadromous Fish, Water Quality, and Tribal Coordination and Consultation. These technical appendices discuss in detail how each of these resources are affected by the proposed alternatives and indicate the interrelationships among the different resources and river uses and the value they have to Native American people.

The following subsections are near verbatim reproductions of tribal statements originally printed in the Cultural Resources Appendix of the System Operation Review, Final Environmental Impact Statement (EIS), which is intended to summarize the collective Tribal perspective of cultural resources. This information is helpful in understanding the significance of cultural resources as they are perceived by Native American peoples. (For additional information concerning the Tribal perspective please refer to the Tribal Circumstances portion of Appendix I, Economics, and Meyer Resources, Inc., 1999).

This perspective is characterized by a broad, holistic view treating virtually all elements and features of nature as cultural resources possessing cultural significance for tribes/traditional American Indian communities. By contrast, Federal agencies working under Federal law definitions of cultural resources tend to emphasize identification and evaluation of physical sites and artifacts with defined boundaries. While tribes and traditional community representatives acknowledge the importance of historic properties, they assert that their definition of cultural resources is broader (extending beyond the definition in the NHPA to include natural resources with cultural significance) with focus on traditional cultural properties.

The following summary of the Tribal perspective was compiled from submitted tribal contract reports, statements made by tribal representatives at coordinating meetings, and other sources. It reflects the agency's understanding of what it has heard from the tribes regarding their view of cultural resources. Specific Tribal representatives and sources are quoted verbatim as being representative of general views that we believe the various tribes hold in common. At the same time, the agency respects the uniqueness of each Tribe and does not intend to imply that the tribes

can be culturally grouped together. While some beliefs are held in common, other beliefs are quite different.

This summary should not be construed as an expression of agreement by the agency with the traditional Native American perspective on cultural resources. However, it is intended to demonstrate a sincere effort to listen to and understand the Tribal positions in general. It should also be noted that each Tribe may have a specific view that may or may not agree with this summary.

1.2.4.1 The Sacredness of the Natural World

Native Americans have traditionally conducted their lives based on the belief that there is a close physical and spiritual interrelationship between humans and nature. This interrelationship extends from the distant past (time immemorial), to the present, and continues infinitely into the future throughout the physical world. It does not assume that humans are superior to the animals or other aspects of nature but, rather, views human existence as an integral part of the natural and spiritual world. All that exists is alive and sacred. The land, rock, water, air, animals, and humans each occupies a unique role in the universe. Native Americans honor their relationships to all natural things. It is for this reason that religion, in the traditional Native American view, is an integral part of life from day-to-day and season to season. Life, for them, is a process of maintaining a balance with the rest of the world and it is this balance that constitutes their world order. Failure to respect the proper place of all things in the natural world would be to upset this balance and could destroy it.

The close bond of the Indian to the natural world is demonstrated in the traditional seasonal cycle of Indian families engaged in subsistence rounds that took them to various places to acquire native food, medicines, and other materials (see sections 2.4 and 2.5). For each Tribal culture, the annual cycle of subsistence formed an integral part of their cultural fabric. According to the Spokane Tribe of Indians who share a tribal perspective with project-affected tribes:

> *Before the construction of Coulee Dam the Spokane people were dependent upon and interwoven with an annual cycle. The removal of any part of this cycle destroys all opportunity of continuing that cycle. Removal of the salmon and related cultural components by the construction of the dam destroyed traditional Spokane culture. They could no longer carry out a traditional way of life with a significant portion of their economy, diet, and spirituality missing (Review of SOR Draft EIS Appendix D, Cultural Resources, page 4).*

1.2.4.2 Unwritten Knowledge

Native Americans deeply respect tribal elders as the ones who traditionally preserve and transmit cultural information and their language down to the younger generation. Thus, the main body of cultural knowledge contained in tribal traditions and practices is unwritten and the process of teaching it to future generations depends on a personal relationship between elders and the younger Tribal members. This knowledge is sacred and cannot be given to just anyone who asks for it. To be ready to receive such knowledge takes preparation and discipline:

> *Now how can you sit across the table and listen to someone like myself or these elders and then put down what kind of impact those alternatives have on our way of life, our way of belief, and our way of teaching? It would be pretty prodigious if you guys can do that. I've been working for eight years trying to learn how to interpret what my elders have been*

telling me. Many times they won't give you the answer you're looking for. . . . You want answers to your questions. Many times elders will throw another question out there to make you think, to make you sit back and think about all of your future. . . . (Mr. Jeffery Van Pelt, Confederated Tribes of the Umatilla (Corps, 1995).

From the traditional Tribal perspective, then, the primary and most authoritative source of cultural information comes from elders. As in the work of anthropologists concerned with understanding a culture and its ethnohistory, information from those people with direct cultural experience, and who function in their society's mainstream, are usually considered of primary value to the researcher. Tribes generally do not place the same value on the work and findings of professional archaeologists as they do the collective understandings of the elders. In the words of Mr. William Yallup, Yakama Indian Nation:

The oral histories would disclose much more than archaeologists can ever find. You have to know the subject matter before you can even talk about it (Corps, 1995: 2-5).

1.2.4.3 Tangible and Intangible Impacts

National Historic Register Bulletin 38 encourages its users to address the intangible cultural values that may make a property historic (N.R.B. No. 38, page 3). From a Tribal perspective, the relationship of their intangible values to various tangible natural and cultural resources is of critical importance. Three examples of this relationship concern salmon, burial sites, and changes due to inundation.

1.2.4.4 Species of Interest: A Natural and Cultural Resource

For affected tribes, there are a wide variety of natural resources found historically within the lower Snake River project's ecosystem. These resources are also of cultural importance to the tribes. Anadromous fish such as salmonids are of great cultural significance to Indian peoples. Salmon were a major food source for most Columbia Basin Tribes. The cultural significance of the salmon is honored in Tribal cultures just as much today as in the past. Traditional ceremonies and the continued respect shown for the salmon have helped ensure their return to fishing grounds. Indian fisherman revere salmon (steelhead included) as one of many divinely provided traditional foods, and as a designated "lead fish" essential on the tables at community dinners. A large catch of fish (enough to both sell and give away) brings social esteem to both the fisherman and the skilled salmon handlers who prepare and serve the catch. Stories and religious songs about salmon bond together individuals, families, Indian society, and cultural places with all aquatic species of interest to traditional Indian people. In an attempt to explain the close inter-relationship peoples of the Yakama Tribe have experienced with the land, and how they have long been sustained by their subsistence places and resources, Chief Meninook stated:

God created this Indian country.... He put the Indian on it. They were created here in this country, truly and honestly, and that was the time this river was started to run. Then God created fish in this river and put deer in these mountains and made laws through which has come the increase in fish and game.... When we were created, we were given our ground to live on, and from that time these were our rights.

My strength is from the fish, my blood is from the fish, from the roots and the berries. The fish and game are the essence of my life. I was not brought from a foreign country and did not come here. I was put here by the Creator.

The drastic reduction in salmon runs over recent decades reflects a major cultural loss to virtually all of the Columbia Basin Tribes, and has altered their community life ways.

1.2.4.5 Native American Cemeteries and Graves

Native Americans traditionally believe that continuity in time connects their ancestors with those living today and those yet to be born. It is believed that each person who lived in the past, who lives now, or who is yet to be born has a name, which is preordained. Death does not end kinship or relationships. Thus, the belief that each living or inanimate thing has its own unique place in the universe extends to the spirit world and across time. Therefore, the burial sites of Native Americans are sacred to them and to disturb the remains of an ancestor for any purpose is a sacrilege.

Our elders have taught us once a body goes into the ground, it is meant to stay there until the end of time (Armand Minthorn in Umatilla Position Paper).

1.2.4.6 Traditional Value of Places

Certain places in the landscape are traditionally considered to be of special significance to the tribes. Vision quest sites, social and political gathering places, and sites associated with stories, tribal history, or community history, have been inundated or are affected by erosion due to reservoir action. In the tribal perspective, this is a loss of cultural resources and a loss of their culture.

1.2.4.7 Responsibility of Federal Agencies

Federal agencies are responsible for effects to cultural resources caused by their undertakings, including operation of dams. As mandated in such laws as the National Environmental Protection Act (NEPA), the NHPA, and American Indian Religious Freedom Act (AIRFA), Federal agencies must consult and collaborate with affected Indian tribes as well as State Historic Preservation Offices (SHPO) and the National Advisory Council on Historic Preservation with regard to proposed project undertakings.

1.2.5 Intrinsic Values

Cultural resources are valued for many reasons including their contributions to aesthetics, artistic expression, humanistic experience, and recreation opportunities. Some of these public values conflict with the need to protect cultural sites. This necessitates public interpretation and education to foster better appreciation and understanding of the resources on the one hand, while actively managing resource protection programs to prevent the destruction of the resources on the other.

1.2.6 Euro-American/Asian-American Site Significance

Some cultural sites are historically significant and of special interest in relation to the period of Euro-American exploration, the fur trade, military history, mining, navigation, agriculture, and early settlement. The Snake River provided the first travel route for Euro-Americans from the Rocky Mountains to the Columbia River Basin. Navigation of the river led to exploitation of its resources and establishment of today's settlements. There are many historical sites that are significant because they document this course of development. Examples of transportation developments include river

landings, grain chutes, and railroad grades. Also of interest is the role of the Chinese in the industrial exploitation of the Columbia River Basin.

1.2.7 Culture History

Culture history refers to events in the history of a culture, particularly the sequence and age of those events. In such inquiries, the determination of the age of deposits through stratigraphy, radiocarbon dating, and use of volcanic ash. The age of landforms, such as river terraces, is also important. Certain cultural sites become significant for the time period that they represent. Examples of sites important for culture history include Marmes Rockshelter in Lower Monumental Reservoir, Windust Caves in Ice Harbor Reservoir, and Granite Point in Lower Granite Reservoir. These sites are significant because they contain evidence for the earliest human occupations in the lower Snake River canyon.

1.2.8 Traditional Cultural Properties

A traditional cultural property can be defined generally as one that is associated with cultural practices or beliefs of a living community that are: rooted in that community's history, and important in maintaining the continuing cultural identity of the community.

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2. Cultural Resources: Existing Environment

2.1 Overview of Area Prehistory

During the period of earliest human occupation, 13,000 to 8,000 years BP, people occupying this area are believed to have foraged for a wide variety of food resources located in different topographic zones. The time between 8,000 to 4,000 years BP witnessed a warming trend and a shift toward more use of plant foods and aquatic resources including salmon and freshwater clams. From 4,500 to 2,500 years BP, people in this area developed pithouse (a semi-subterranean dwelling) villages and further intensified the use of plant and aquatic foods (e.g., clams). From 2,500 to 250 years BP, the number of pithouse village sites expanded as did the use of salmon and plant foods. The bow and arrow was introduced during this time. The last 250 years coincide with the historic and ethnographic period from the acquisition of the horse by native peoples in the early 18th century to their displacement to reservations in the mid-19th century and the settling of the area by Euro-Americans.

Prehistoric peoples lived in villages along intermediate and major sized streams. Temporary camps were also used but for only short periods of time or for special purposes. Food resources consisted of various species of fish (primarily salmon and steelhead), plants, and animals collected during an annual subsistence round based on the time of year each food source was available.

The prehistory of the lower Snake River Basin may, like much of North America, span approximately 13,000 years. However, little is currently understood of this very early time and for the few archeological sites thought to be of this age, more research is needed for scientific confidence. More conservative views of early human prehistory place the earliest human occupants or Paleo-Indian cultures in the Snake River Basin between 10,000 to 8,000 years BP. During this time, small numbers of native peoples may have inhabited large territories, traveling within them to exploit seasonally or locally abundant resources, especially large hoofed mammals. People relied on residential mobility rather than intensive food production and storage to overcome seasonal food scarcity. Where conditions were favorable, people exploited mammoth, mastodon, camel, and horse, which became extinct during or shortly after this period. Paleo-Indians also hunted species such as bison, mountain sheep, and deer, which were larger than their modern descendants (Butler, 1986).

Prehistoric peoples also exploited favorable fishing sites, such as stream confluences and river narrows, only seasonally during this time period. Peak salmon runs made salmon harvest at these sites efficient at certain times.

The time between 8,000 to 4,000 years BP was characterized by a continental warming and drying trend (Aikens, 1993). This influenced the distribution of vegetation zones. The modern climatic pattern was established by approximately 4,000 years ago. While local inhabitants continued to occupy the area in low numbers and relied on residential mobility, there was a shift towards using more plant foods and aquatic resources including salmon and freshwater clams. Sometime around the beginning of this period the spear thrower and dart replaced the thrusting spear as the dominant weapon technology.

From 4,500 to 2,500 years BP, people in the area developed pithouse (a semi-subterranean dwelling) villages and further intensified the use of plant and aquatic foods. Between 2,500 to 250 years BP, the number of pithouse village sites expanded, as did the use of salmon and plant foods. The bow and arrow was introduced at the beginning of this period. Population densities continued to grow throughout this period (2,000 to 1,855 BP) and food production/harvest processes were intensified.

During this time period, there was a greater use of upland/mountain ecosystems. The food storage system observed over this time period, particularly the dried salmon, tubers, and berries for winter, characterized the kind of consumption. By the 1700s, local southern Plateau Culture Area bands had well-established homelands that encompassed sections of the lower Snake River. These peoples spoke languages from the Sahaptian language family and are known in the literature as the Nez Perce, Palous, Cayuse, and Walla Walla. Other peoples including those of the Wanapum, Umatilla, and Moses bands cross-utilized the homelands of the established Snake River bands.

2.1.1 Lower Snake River Archaeological Sequence - Leonhardy and Rice

In 1970, Leonhardy and Rice developed a cultural sequence for the lower Snake River that has become the hallmark approach to defining archaeology along this stretch of the river. It is based on the analysis of artifact assemblages from 19 sites, which happen to be within the Feasibility Study area. The research data was organized into four time periods and six phases (Figure 2-1). The time periods included the Pioneer, Initial Snake River, Snake River, and Ethnographic. The Pioneer period encompassed the late Paleoindian Windust phase and the early to middle Holcene Cascade phase. The Initial Snake River period included the Tucannon phase, dating from about 4,500 to 2,500 BP. While the Cascade phase was believed to have evolved out of the earlier Windust phase, no such continuity was assumed between the Cascade and Tucannon phases. The Snake River period extended from about 2,500 BP to historic contact, and was seen as a continuum of in place development with its roots in the Tucannon phase. Two phases are included in this period, the Harder and Piqunin. The Harder phase was further divided into an early and late subphase. Early Harder assemblages date from ca. 2,500 BP to about 1,000 BP, and late Harder assemblages from about 1,000 to 700 BP. The subsequent Piqunin phase dated from 700 BP to "before AD 1700" (300 BP). The Ethnographic period included only the Numipu phase, which lasted from about AD 1700 (300 BP) to contact.

Phases were defined in terms of both their formal content and restricted distributions in time and space.

2.2 Native Peoples

At the time Euro-Americans arrived in the Pacific Northwest they found numerous Indian groups living throughout the Columbia River Basin. Evidence for the long presence of native peoples in the region is indicated by the large geographic distribution, and diversity of dialects represented in the languages belonging to the Penutian language stock. Historically, the lower Snake River was occupied by numerous bands of Indians peoples who spoke dialects of the Cayuse, Northeast Sahaptin, and Nez Perce languages. While most of these native languages are still spoken, Cayuse survives only as a small vocabulary group inter-mixed into the other two languages. Middle Columbia and lower Snake River bands shared subsistence-based economies supported by hunting, fishing, and foraging. Political organizations consisted of loosely associated villages of family groups, each village with its own general territory and leadership. While these bands were fairly

Snake River Sequence

Date (B.P.)	Phase	Artifact Assemblage		
Present 250	Numipu	Euroamerican trade goods Decrease in Aboriginal Technologies		
500 1000 1500 2000 2500	Late Subphase Harder Early Subphase	Small corner notched points Lanceolate & pentagonal knives Small end scrapers Bone Beads Utilized flakes Rectangular stemmed points Composite harpoon elements	Pestles Net weights Expanding stemmed points Twined basketry & cordage Perforated elk teeth Decorated pestles Bone matting needles	Cobble spall scrapers Hopper mortar bases Bone awls & needles Shell Artifacts (Olivella & Dentalium)
3000 3500 4000 4500	Tucannon	Contracting stemmed points Corner & side notched points Side & end scrapers Net weights Pestles Utilized cobble spalls Bone awls	Bone shuttles Pounding stones Hopper mortar bases Cobble spall scrapers Utilized flakes Antler wedges	
5500 5000 6000 6500	Late Subphase Cascade ca 6700 Mazama Ash	Cold springs side notched points Lanceolate (Leaf-shaped) point Large lanceolate & triangular knives Tabular & keeled scrapers Large cobble spall scrapers Small grinding stones	Large utilized flakes Pounding stones Manos	
7000 7500 8000	Early Subphase	Edge ground cobbles Bone atlatl spurs	Bone needles Atlatl weights	Bone awls Olivella beads
8500 9000 9500 10,000 10,500 11,000	? Windust ?	Straight or contracting stemmed points Uniface & biface lanceolate points Lanceolate & oval knives Multiple faceted burins Large cobble scrapers Utilized flakes Bone atlatl spurs	Scrapers Uniface & biface choppers Utilized spalls Bone needles/awls Olivella beads	

Figure 2-1. Archaeological Chronology for the Lower Snake River

Source: Leonhardy and Rice, 1980 (revised version)

distinctive, they shared similar customs, languages, and jointly used major subsistence, and trade markets. Native bands also formed a larger southern Plateau Culture Area society through economic and political alliances.

Native life ways were based upon subsistence economies, which required families to observe annual seasonal migrations throughout their homelands and to places elsewhere within the region. People harvested foods as they became ready and participated in a trade network involving a other bands. The seasonal activities of the Sahaptian-speaking people is fairly representative of the subsistence practice throughout the non-mountainous parts of the Columbia River Basin in early historic times (Hunn, 1990). In general, these peoples lived in winter villages near the Snake River or on the lower reaches of its major tributaries, subsisting on food stores during the winter, supplemented by hunting and fishing. They lived in large, multifamily lodges covered with tule mats.

In early spring, families harvested vegetable foods from the plains and riverine foothills, and fished the spawning runs of suckers in major rivers and primary tributaries. Later, they roamed uplands further from the winter villages to collect bitterroot and other vegetable foods for long-term storage. In May, they went to favorite fishing sites on the main river for the spring chinook runs. By late May flooding made fishing difficult, so they went to the mountains to escape the summer heat, and to harvest and dry large quantities of huckleberries, and hunt deer and other game.

Sahaptian speaking peoples returned to the river to harvest anadromous fish species between July and October. Of great dietary importance was the fall chinook that came up stream during September. The chinook salmon runs produced large quantities of stores for winter food. It is estimated that as much as one third of the southern Plateau Area peoples' annual diet may have come from aquatic resources such as salmonid fish species. Food plants may have supplied an additional 50 percent of their annual food supply, with game and huckleberries making up much of the remaining amount (Hunn, 1990).

Seasonal subsistence rounds took family groups from winter villages within major river basins to seasonal camps and subsistence sites throughout the uplands. With the introduction of the horse in the mid-1700s, the range of trade and subsistence rounds for some bands (e.g., Nez Perce) greatly increased. Bison hunting on the plains became an annual or frequent activity that resulted in elements of the Plains culture being introduced into the Plateau Culture Area. The Snake River was an important winter refuge and a primary source of subsistence fishing during the spring and fall. Fall and winter big game activity, and spring through fall plant gathering activities completed the seasonal round of life of Snake River bands. Trade contacts evened out some of the inequities of resource availability in any given bands' territory and brought these Indian groups together into large inter-related economic and political networks. Plateau cultures such as the Nez Perce, Cayuse, Walla Walla, Umatilla, and Palous were internally pacifistic, but could be intensely aggressive towards Indian groups from outside the southern Plateau (e.g., Blackfeet tribe of the Great Plains and the Northern Paiute of the Great Basin).

Horses were traded into the southern Plateau from New Mexico some time after 1730, changing native peoples' mobility, warfare, and subsistence logistics. European diseases such as smallpox arrived with the crews of exploring oceanic vessels even before trading ships began to arrive on the Pacific coast in the 1790s. Northwest Indian populations declined dramatically after 1770 because of introduced diseases. By 1830, the Northwest had lost approximately 50 percent of its native population to disease (Boyd, 1985) and more than 80 percent by 1870. Prior to the arrival of settlers

overland from America, relations between Indians and Euro-Americans were mostly amicable and governed by mutual interest in trading of furs, foods, and other items for manufactured goods.

2.2.1 The Historic Period

European and American influence began in the early 1700s with European trade items transported into the Snake River Basin by Native American traders. First contact with Euro-Americans in the region was made in 1805 when the Nez Perce encountered the Lewis and Clark Corps of Discovery. The Lewis and Clark Corps of Discovery followed the course of the lower Snake River, traveling through the homelands of the Nez Perce, Palous, Cayuse, and Walla Walla, on their journey to reach the Columbia River and the shores of the Pacific Ocean (Coues, 1893).

Beginning in early 1855, the United States Government entered into a series of treaties with many of the Plateau Culture Area tribes/bands. Some Columbia and Snake River area bands participated in the treaty council held by Oregon Territorial Governor Isaac Stevens at Walla Walla. This treaty formally created the Federally recognized tribes of the Yakama, Umatilla, and Nez Perce. Plateau tribes like the Warm Springs were formed through the Middle Oregon Treaty, and the Salish-Kootenai tribes through the Hell-Gate Treaty. These treaties were all negotiated in 1855 and are sometimes referred to as Stevens Treaties after Oregon Territory's Governor Stevens who was the lead United States Government negotiator. Treaty making in the 1860s further defined the Nez Perce reservation and tribal rights. As non-Indian settlers and miners began moving into the region between 1855 and 1880, conflicts arose with the local tribes, resulting in the Indian wars of 1855-58, the Snake War of 1866-68, the Nez Perce War of 1877, the Bannock-Paiute War of 1878, and the Sheepeater War of 1879. The Governor Stevens treaties with Plateau bands required these Federally recognized tribes to relinquish part of their homelands as defined by Stevens, known as "ceded lands." However, through treaty negotiations these tribes retained certain pre-existing rights allowing them to fish at usual and accustomed areas. Treaty negotiations also allowed tribes to hunt, gather, and graze livestock on open and unclaimed lands.

2.3 Cultural Resources: Affected Area

Cultural resources are found throughout the Snake River system. Most scientific information generated about them has been the result of archaeological studies associated with the construction of Federal dams in the area of this study. There is, however, more than one view of what constitutes cultural resources. The academic and legal definitions, while including many aspects of culture, tend to focus on tangible evidence, such as sites and artifacts. Many traditional communities and some anthropologists find such emphasis and corresponding resource definitions to be limiting. Local tribes view their unique heritage and cultural/spiritual relationships with the earth and natural resources as being connected with and affirmed by cultural resources. In the tribal view, natural resources are an integrating aspect of cultural resources. The impacts to natural resources should be addressed and understood together in the context of traditional cultures. These somewhat differing interpretations of Federal legislation reflect how various groups of people would have cultural and natural resource laws operationally interpreted by Federal agencies.

The following discussion is based on the more narrow definition of cultural resources. The expanded, traditional tribal view of cultural resources is addressed in the Meyer Resources, Inc., 1999.

2.3.1 Cultural Resource Management

The legislative foundation for the Cultural Resource Management (CRM) era was established through the NHPA and NEPA. By the mid-1980s archaeologists began to shift their research focus away from the lower Snake River canyons to the adjacent uplands. This change in CRM focus was prompted by the logical need to expand research to include the uplands and to fulfill regulatory requirements to identify all historical properties. Since the end of the reservoir impoundment era, the focus of CRM in the Snake River Basin has shifted from large-scale salvage programs to the identification and evaluation of cultural properties, and, where appropriate, determination of effect studies of proposed impacts to cultural properties.

By the mid-1980s, archaeological attention began to shift away from the lower Snake River canyons to the adjacent uplands. This change in CRM focus was prompted both by logic and necessity. Logic as expressed in the new Binfordian (from Lewis Binford, a major archaeological theoretician), regional research designs which required that whole basins be considered, not just riparian strips. Just as important was the compliance mandate imposed on government agencies to inventory and manage cultural resources. Much of this inventory work and resource documentation were done in-house.

Between 1947 and 1954, most of the planned dam sites and reservoirs for the Columbia River system were surveyed by Smithsonian archaeologists. Salvage operations were then carried out at The Dalles and McNary Dam projects. The Smithsonian conducted these early archaeological surveys, known as the River Basin Surveys, from a field office at the University of Oregon. These surveys also extended to the lower Snake River region. During this era, about 10 percent of the inventoried sites were partially excavated prior to inundation or construction impacts.

After 1955, the National Park Service administered archaeological surveys in this area from its Western Regional Office in San Francisco. Working through regional colleges and universities, these activities prompted the major universities to establish and maintain an inventory of archaeological site records. Most of this original inventory information was passed on to the respective SHPOs during the 1970s, following their creation under the NHPA. During this time, about 5 percent of sites inventoried in the project areas were sampled before they were destroyed or inundated. Since the 1974 amendment to the Reservoir Salvage Act of 1960, Federal agencies such as the Corps have professionally managed cultural resources activities under their jurisdiction at the Federal reservoirs under their jurisdiction.

2.4 History of Cultural Resources Surveys

The United States National Museum conducted the earliest professional studies describing cultural resources in specific Columbia River Basin reservoirs (H.W. Krieger, 1927, 1930). This research stemmed from the construction of Bonneville Dam.

The Federal government did not actively participate in cultural resources activities in the Columbia River Basin until the Corps, the National Park Service, and the Smithsonian Institution signed the 1945 Interagency Archaeological Salvage Agreement.

2.5 River Basin Surveys

As World War II drew to an end in the summer of 1945, the Corps and the BOR began plans to implement a nationwide program of dam and reservoir construction, with much of the effort focused

on the Missouri and Columbia-Snake basins. Plans to dam the lower Snake River accelerated after 1950 with the intensification of the Cold War and increased demands for hydropower to manufacture aluminum (Ashworth, 1977: 88). The National Park Service and Smithsonian Institution became involved when the potential impact to archaeological resources was recognized, establishing an office of River Basin Surveys. The chief of the survey office warned that "about 80 percent of the archaeological remains in this country are located in places where the damming of rivers and the formations of reservoirs will obliterate them for all time" (Roberts, 1948: 13).

Funding was so limited and time so short in the late 1940s that data recovery excavations were initiated in only nine reservoirs. Only one of those nine (McNary) includes shoreline on the Snake River. Eventually, the Columbia Basin Project of the River Basin Surveys conducted reconnaissance surveys of the Ice Harbor, Little Goose, Lower Monumental, and Lower Granite reservoirs on the lower Snake River.

Unfortunately, lack of time and adequate support for the River Basin Survey teams resulted in a series of hastily produced mimeographed reports (Sprague, 1984) that badly underestimated the quantity and variety of cultural resources in the lower Snake region. It has been observed that in the Lower Granite Reservoir "the initial survey found seven sites, while a later survey reported almost one hundred sites" (Sprague, 1973: 262). The first River Basin Survey report for the lower Snake recorded 15 sites in the Ice Harbor flood pool, 10 at Lower Monumental, 19 at Little Goose, and 12 at Lower Granite (Osborne, 1948). It is unclear whether the Lower Monumental flood pool was ever re-examined before inundation, but a re-survey of the 94-mile (151 kilometers) perimeter of the Little Goose flood pool recorded 71 sites (Nelson, 1965).

2.6 Reservoir Impoundments

The era of reservoir impoundment along the middle and lower Snake River lasted only 22 years, yet created a total of 289 miles of artificial pools behind McNary (1953), Brownlee (1958), Oxbow (1961), Ice Harbor (1961), Hells Canyon (1967), Lower Monumental (1969), Little Goose (1970) and Lower Granite (1975) Dams. Salvage excavations were conducted on known sites in order to recover important scientific information before the raising of the reservoirs. An unprecedented volume of archaeological data in the form of site reports and academic theses and dissertations were produced. Nevertheless, few of the rescued site assemblages have been reported in a complete fashion, and many have never been analyzed or even described. A major challenge for future cultural resources management studies will be the analysis, description, and synthesis of Corps archaeological collections. Both cultural resource management needs and considerable research opportunities exist for resources accessible in reservoir systems' fluctuation and indirect impact zones.

2.7 Lower Snake River Cultural Resources

The majority of the archaeological research in the lower Snake River occurred in response to plans to construct hydropower facilities. This work identified most of the prehistoric sites now known for the lower Snake River Basin and retrieved some scientific information before the proposed reservoirs were flooded and access to certain sites was lost. A minority of sites and archaeological districts were evaluated for NRHP eligibility during and shortly following this time period. In recent decades, Federal funding for such archaeological work has not been available. Consequently,

cultural resources management has focused on areas needing immediate protection near known sites, inadvertent discovery sites, and/or Federal activities.

A general overview, gathered from what is currently known, is presented here. There are approximately 445 known archaeological sites located within the four lower Snake run-of-river reservoirs (Lower Granite—136; Little Goose—76; Lower Monumental—173; and Ice Harbor—53). Identified prehistoric sites include villages, fishing sites, burials, rock art (pictographs and petroglyphs), storage pits, and temporary camps. Historic sites include homesteads, mining sites, forts, towns, and trading posts. At present, two archaeological districts (Windust Caves and Palouse Canyon) and three sites (Burr Cave, Marmes Rockshelter, and Hasatino) are listed on the National Register of Historic Places. In addition to National Register status, Marmes Rockshelter is also a designated National Historic Landmark.

2.7.1 National Register Sites and Districts

The following list contains the names of the National Register sites and listed or eligible districts (a group of closely associated archeological sites based on NHRP criteria) at Federal Snake River system dams and affected reaches. Sites included in the following list represent about ten percent of known sites that the Corps manages in the lower Snake River.

National Register Sites and Districts at the four Lower Snake River Reservoirs

1. Ice Harbor Dam, Lake Sacajawea (Walla Walla District, Corps)
   a. Windust Caves Archaeological District (listed)
   b. 45FR272 (listed)
2. Lower Monumental Dam, Lake West (Walla Walla District, Corps)
   a. Palouse Canyon Archaeological District (listed)
   b. 45FR50 (listed National Historic Landmark)
3. Little Goose Dam, Lake Bryan (Walla Walla District, Corps)
   a. No sites currently listed or determined eligible
4. Lower Granite Dam, Lower Granite Lake (Walla Walla District, Corps)
   a. 10NP151 (listed)
   b. Archaeological sites 45-WT-78/79 (determined eligible)

3. Geomorphology and its Relationship to Cultural Resources

3.1 Geochronology/Geological History of the Region

In the Snake River Basin, the measurement of time intervals on a geological scale has involved the dating of rates of sedimentation, flood sequences, ancient soil deposits, and volcanic ash deposits. Fryxell (1963) summarized geological data from archaeological sites between the Ice Harbor and Lower Granite floodpools, and paleontological sites from the Palouse Hills and Channeled Scabland.

Fryxell interpreted the postglacial alluvial history of the lower Snake River as follows: Detailed geological examination of archaeological sites in the lower Snake River canyon confirms the presence of human cultural materials associated with stream gravels on narrow low-level erosional terraces, gravel bars, and in caves above the present high-water marks. The absence of late-glacial Touchet sediments on these gravel bars and terraces, inclusion of remains of extinct bison species in them, and deposits of volcanic ash on them bracket their development as no older than very late or immediate post glacial, and no more recent than the Thermal Maximum.

A composite geoarchaeological chronology for eastern Washington was prepared by Fryxell and Daugherty (1963) and is reproduced here in Figure 3-1. It shows the relationship between postulated shifts in vegetation, climate, material culture, and inferred human economy for the Anathermal (14,000 to 8,000 BP), Thermal Maximum (Hypsithermal or Altithermal, 8,000 to 4,000 BP), and recent periods. Anathermal dating is supported by comparative typology of cultural materials recovered from the archaeological sites. The Anathermal terraces themselves are minor scars incised in constructional terraces, which bear giant ripple marks produced by Scabland floods and a veneer of Touchet silts and sands. Thus, the position of the Snake River throughout most of its course from Lewiston to the Pasco Basin has remained essentially stable since the close of glacio-fluvial discharge into the Snake from the Cordilleran Ice Sheet. Similar conclusions appear valid for many segments of the Columbia River above its confluence with the Snake River.

Accumulation of floodplain loess (wind blown soil) along the entire valley, at a period when flow of the Snake was at least as low as now and possibly lower, occurred during Altithermal time, though the upper and lower time limits of deposition have not yet been firmly established. Radiocarbon dates from hunting camps and village sites show that accumulation of this loess has not continued during the last two thousand years, but has locally been replaced by erosion and redeposition of windblown sand.

Rapid erosion of these finely textured flood-plain deposits coincided with homesteading and agricultural development of the Columbia Plateau, which continues today at an accelerating pace. Reactivation of large dune areas occurred simultaneously (Fryxell, 1963: 11-12).

3.2 Late Pleistocene Floods

Accurate dating of the aggradation of the Snake River behind flood debris that plugged the canyon above the confluence with the Palouse became a major research problem during the 1960s and 1970s. Data recovery excavations in the Lower Monumental and Lower Granite floodpools had one objective: the establishment of the absolute basement dates called for by Fryxell in 1963.

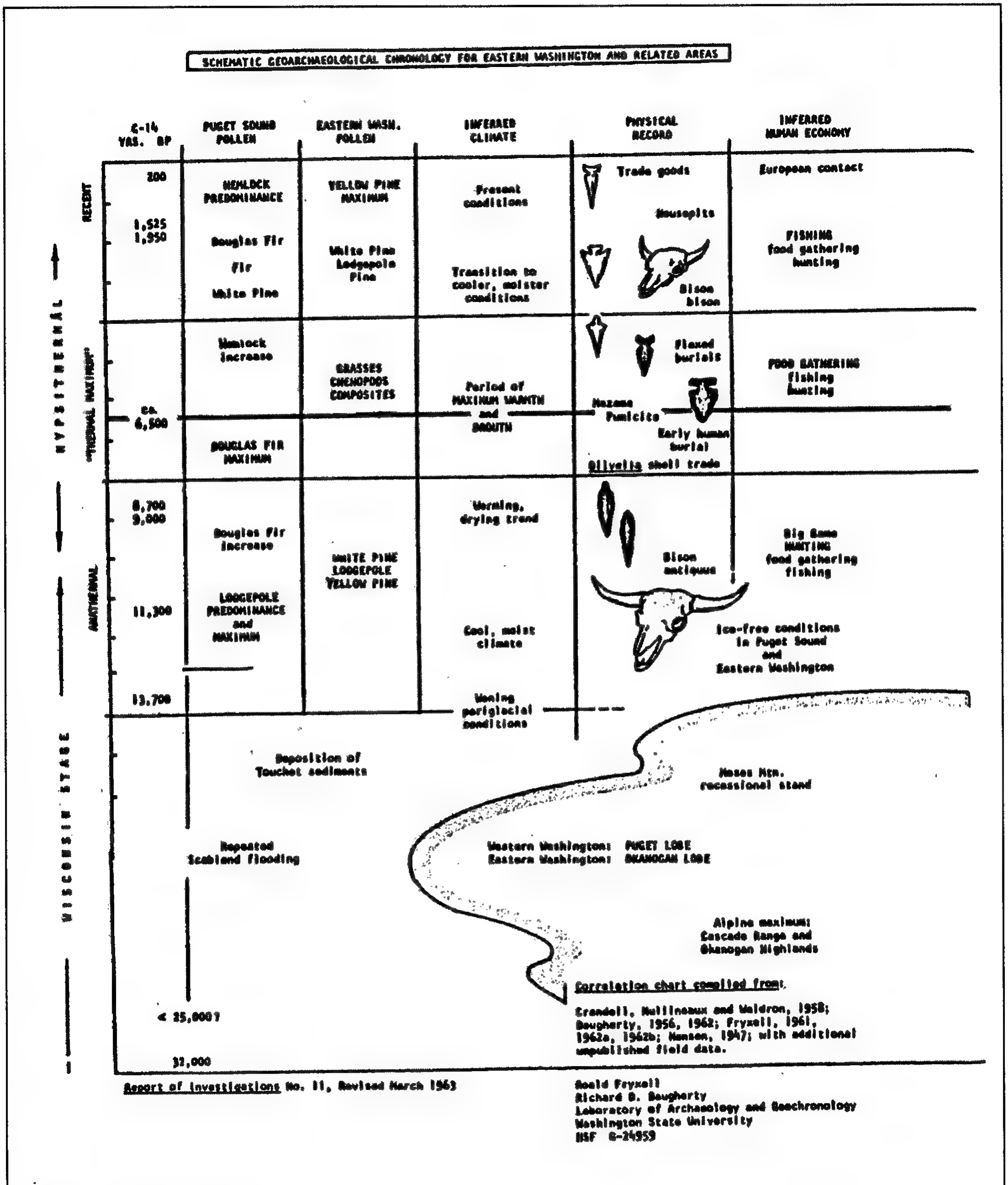


Figure 3-1. Geochronology for the Lower Snake Region

Slackwater sediments found in Wawawai, Steptoe, and Alpowa canyons and at Granite Point were interpreted by Leonhardy (1970: 70-71) as evidence for a late Pleistocene Lake that stood at an elevation of 900 feet (274 meters). The lake was attributed to backflooding from a discharge from glacial Lake Missoula that occurred at about 12,310 BP, based on interbedded lenses of Glacier Peak ash. The age for the Glacier Peak ash came from a radiocarbon date of 12,310 +/-310 BP obtained on shells of freshwater mussels found in pumice in lower Grand Coulee (Fryxell, 1965: 1288-1289).

Leonhardy suggested that the lake drained between 11,000 and 10,000 BP, or about 1,300 to 2,300 years after it formed. Leonhardy also suggested that the first humans came into the lower Snake River valley between 11,000 and 9,000 BP, probably about 10,000 BP (1970: 71-73).

Hammatt (1977: 173) argued that the last of the scabland floods from glacial Lake Missoula swept up the Snake River canyons and drained out again sometime after 14,000 -13,000 BP, but before 10,600 +/-200 BP (Figure 3-2). The earlier date range was based on charcoal and St. Helens S tephra found in sediments beneath slackwater deposits. The latter date is from cultural deposits at Wildcat Canyon on the lower Columbia River, which Hammatt called the earliest archaeological date within the scabland drainage.

Hammatt suggested that:

> *...it was entirely possible that people may have been present in the Snake River canyon when it was filled with flood water to depths of over 500 vertical feet (152 meters). It is possible that the earliest documented occupation in the canyon is limited in time depth not by the arrival of the people, but by the selective preservation of only those sites which post date the last flooding episode.*

The earliest consistently and securely dated human occupation in North America is the Clovis culture, which flourished between 11,500 and 11,000 years ago (Haynes, 1982: 383). So far, the only dated Clovis site in the Pacific Northwest is the East Wenatchee cache (45DO432). Here, particles of Glacier Peak ash incorporated into silica accretions on the undersides of two superimposed cache blades indicate that the artifacts were deposited on a ground surface 11,250 years old (Mehringer and Foit, 1990).

The distinctive fluted lanceolate points of the Clovis culture have not yet been found in situ in the lower Snake region. This absence, coupled with the above hypotheses concerning the chronology of backflooding from the glacial Lake Missoula discharges, has led several archaeologists to suppose that the early Holocene Windust culture moved in to a blank slate of a landscape when they settled the Snake River canyons about 10,000 BP.

Thus, in Leonhardy's interpretation, early Paleoindian (Clovis) cultures could not occur in the lower Snake because the canyons were flooded by a great lake during the crucial interval between 11,500 and 11,000 BP. In Hammatt's interpretation (Figure 3-3), early Paleoindian hunters may have camped in the valley, but their traces were probably removed by catastrophic backflooding between 13,000 and 10,600 BP.

An alternative interpretation is suggested by the following observations. First, at Marmes Rockshelter in the Palouse canyon, there are radiocarbon dates on cultural remains of 10,800 +/-300 and 10,750 +/-300 (Sheppard et al., 1987: 122). These are slightly earlier than the Wildcat Canyon date and may indicate that people have been in the study area since at least 11,000 BP. An

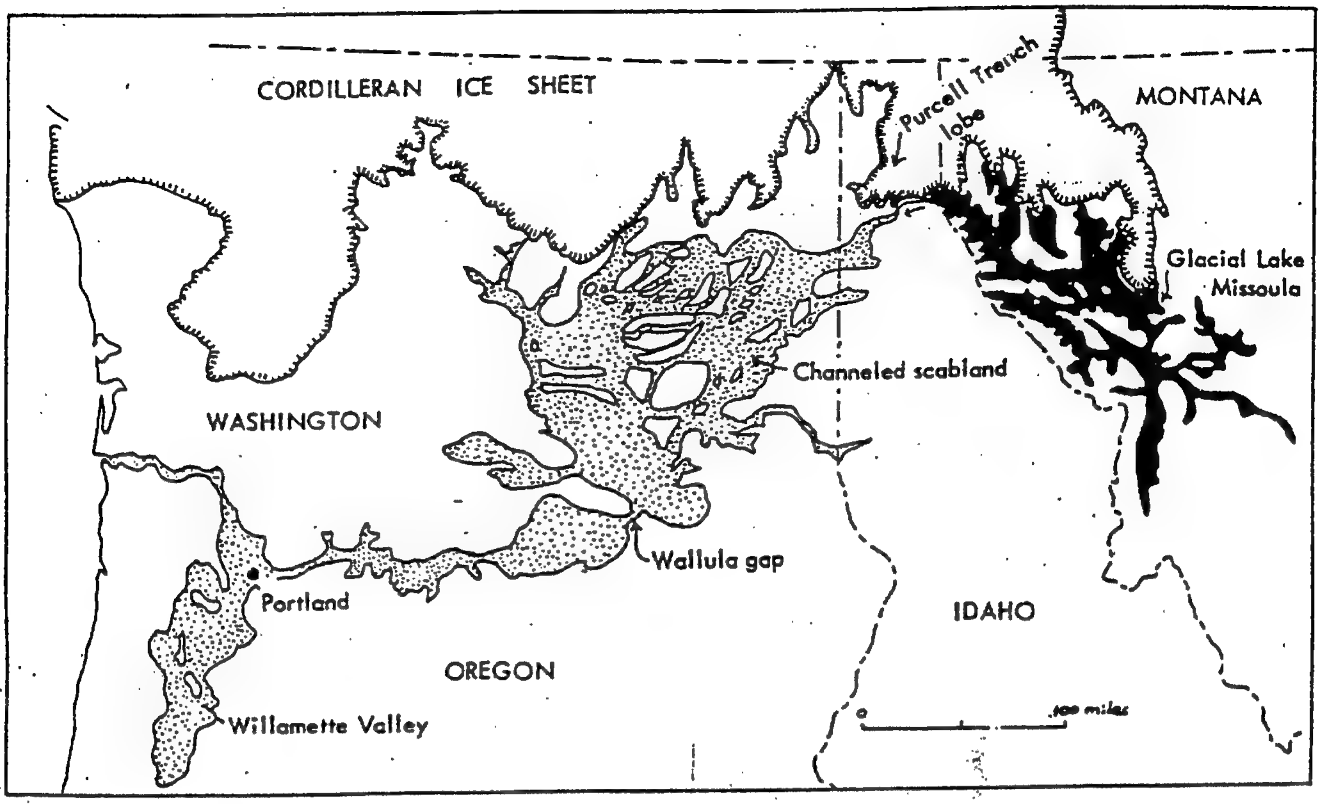
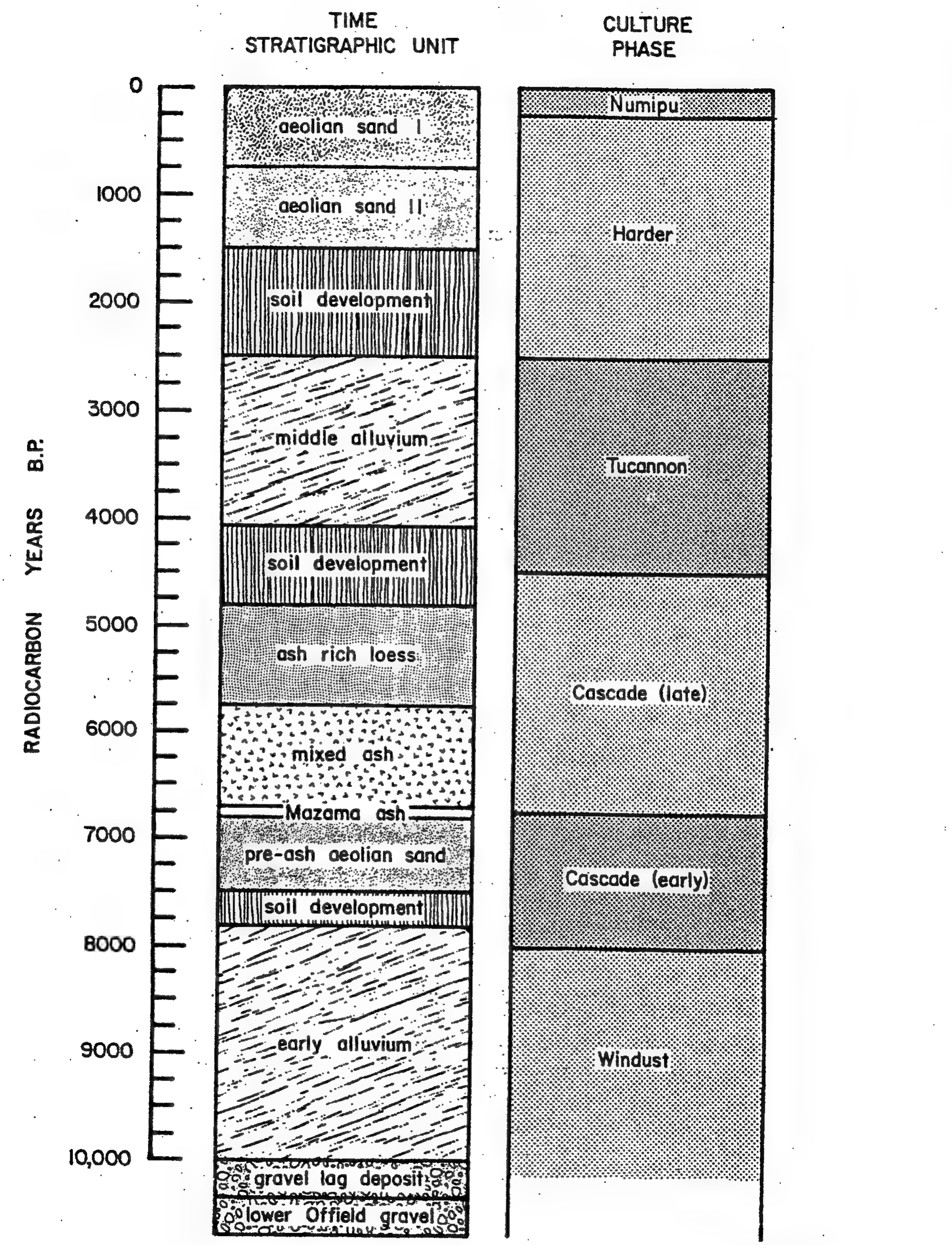


Figure 3-2. Area of Pacific Northwest Affected by Missoula Flood Between 15,300 and 12,700 BP

Source: Maley, 1987: 165; and based on Waitt, 1985



Source: Hammatt, 1977, figure 47

Figure 3-3. Relationships of Late Quarternary Stratigraphy with Cultural Chronology

unidentified tephra layer occurs below these dates at Marmes. Given its position, it is probably either the Glacier Peak or St. Helens ash (Sheppard et al., 1987: 121). The former is now dated at 11,250 BP (Mehringer et al., 1977), the latter at about 13,000 BP (Mullineaux, 1986: 20). The implication is that the lower Palouse canyon and presumably the lower Snake River valley did not experience catastrophic backflooding after 11,250 BP and perhaps not after 13,000 BP.

Second, the rhythmic slackwater beds in backflooded canyons, seen by Leonhardy as evidence of turbidity currents in a great late Pleistocene lake that backed up the Snake River from the Wallula Gap, have recently been reinterpreted as individual flood events produced by scores of separate floods. Instead of one, or a very few great floods between 22,000 and 18,000 BP (Baker, 1973), the most recent hypothesis now posits 40 or more floods resulting from repeated filling and emptying of glacial Lake Missoula during a 2000 to 2500 year interval between 15,300 and 12,700 BP (Waitt, 1985: 1283-1285).

One implication of the Waitt hypothesis is that the study area was available for Clovis occupation between 11,500 and 11,000 BP. Whether early Paleo-Indians actually did settle in the lower Snake River canyons remains to be learned.

3.3 Major Geologic Features of the Lower Snake River Basin

The northwestern Snake River Basin consists of the Northern Hills, composed principally of the Palouse Hills and the eastern tract of the Channeled Scablands in southeastern Washington. The Northern Hills slope downward gradually from the northwestern arc of the Northern Mountains region toward the Columbia River. The area includes about 3,782-square kilometers, almost all of which is below 1,219 meters in elevation. The lowest point of the region is at 78 meters (256 feet) in elevation at the confluence of the Snake with the Columbia.

3.4 Geomorphic Evaluation of the Project Area

There are strong relationships between geomorphic, ecological, and cultural elements of the environment. Although many of the cultural and ecological values have not been studied in detail or may not be widely understood, geomorphic conditions are generally studied and reasonably well understood. The geomorphic analysis procedure can also be adequately performed at the level of detail appropriate for an EIS without the need to undertake additional investigation. For instance, the soil and geologic materials and physiography have been mapped and generally analyzed at a regional level. Regional hydrology is also well documented in other appendices. Also, the formulation of management and protection plans for the physical preservation of cultural resources can be undertaken. (See Appendix E—Existing Systems and Major System Improvements Engineering and its section entitled, "Cultural Resources Protection Plan.")

The procedure is based on deductive reasoning. It will predict how certain material elements of cultural resources will respond when geomorphic processes act on them. This is necessarily a qualitative analysis of effects to cultural resources that considers the complex interplay between the susceptibility of different landforms to erosion effects; the strong influence of system operational features on reservoir environments, and the generally high density of cultural resource values that are associated with these landscapes. To some extent, local Corps' knowledge or operational lore is used as the basis for generalizations concerning how the lower Snake River hydropower system operate and the effects of the operational features on landforms. This knowledge is combined with

the accumulated experience and information gained from cultural resource evaluations following past Federal actions in the Snake River Basin.

The analysis also assumes that cultural resource values are a fundamental part of the environment and whatever affects one part would, or may also affect other parts. Given the broad definition of cultural resources and their complex inter-relationship, significant cultural values occur on all landform types. Landforms that are too steep for habitation, for example, may have spiritual significance stemming partly from their inhospitable or inaccessible location. Cultural resource values associated with such sites may be particularly significant because of their rarity. These sites also have archaeological significance because they can provide information about specialized activities and events that would remain unknown if such areas were overlooked. Inundation, erosion and landform change at any place in a reservoir is therefore a potential concern for cultural resource management.

3.5 The Alternatives

Feasibility Study alternatives related to cultural resources are summarized as follows:

- Under Alternative 1—Existing Systems, the hydropower facilities would continue to operate as originally designed, and reservoir fluctuations would not change. For the most part, geomorphic processes have reached a near-equilibrium under operations since the impoundment of the reservoirs. However, reservoir adjustments to optimize hydropower production, commercial navigation, irrigation, and recreation have caused numerous impacts. Ongoing erosion has stabilized to some extent on the reservoirs. Some of this effect is due to bank stabilization structures in place at various locations, which are designed to slow or halt erosion.
- Under Alternative 2—Maximized Transport of Juvenile Salmon and Alternative 3—Major System Improvements, current conditions (as described above) would continue.
- Under Alternative 4—Dam Breaching, the lower Snake River would be returned to unimpounded, yet controlled conditions. Some existing bank stabilization measures could be made superfluous by the Dam Breaching alternative. Many, however, would still provide a level of protection from impacts other than those for which they were originally designed.

3.6 Impacts of Erosion and Sedimentation Process

The effects of a reservoir on its environment begin before the impoundment is filled. The effects of vegetation clearing and earth-moving are primarily mechanical. They are to some extent temporary in nature, although the rearrangement of certain physical elements of the environment is permanent. Because this study addresses only changes in the operational strategies of the reservoirs, the initial impacts of reservoir construction are considered only to the extent as an assumption that cultural resource values are sustaining ongoing, adverse impacts from inundation and current operational actions. It is also assumed that the level of impacts due to reservoir operations change through time.

There are four basic reservoir areas that are important to understanding effects to cultural resources: 1) The Inundation Zone—the main body of water making up a reservoir excluding its lateral edges; 2) Zone of Fluctuation—the reservoir area where water levels range between high water to low water marks and includes land not always under water; 3) Zone of Direct Impact—the reservoir area

where cultural resources are located and potentially in contact with water levels; and 4) Zone of Indirect Impact—the land adjacent to a reservoir that is not exposed to inundation (Figure 3-4).

In order to minimize impacts to cultural resources within a hydropower reservoir environment, the ideal operational strategy would be one in which the reservoir is filled rapidly and there are no reservoir level fluctuations. The direct impact zone of the reservoir environment where cultural resources are subject to adverse effects would ideally have gently sloping, stable landforms characterized by either protective vegetation cover or solid rock formations.

Under such an ideal scenario, adverse effects to cultural resources would be confined to the inundation zone. The study area contains some of these ideal impact zone environments, however, it also contains large areas with steep and unstable landforms. In these less-than-ideal areas, natural erosive forces and difficult terrain constitute problems for cultural resource management.

The first three FR/EIS alternatives (Existing Conditions, Maximized Transport of Juvenile Salmon, and Major Systems Improvements) would essentially have the same effects on cultural resources because no changes in reservoir regulation to the direct and fluctuation zones are planned under these alternatives. Thus, a clear understanding of current impacts on cultural properties is considered sufficient to understanding expected effects of the alternatives. However, it should be noted that potential upward trends in anadromous fish species populations could result in slightly increased use of fishing sites along some systems.

Within the permanent reservoir area, the dominant effects on cultural resources are from inundation and the biochemical processes active in that environment. Sedimentation and underwater erosion processes are active but secondary factors. Previous geomorphic analyses have viewed cultural resources in the permanent reservoir area as being protected but not necessarily preserved. In terms of the adverse effects on cultural values this portion of the environment sustains, inaccessibility due to inundation and burial in sediment have had the greatest impact. The two geomorphic processes that have dominated in this environment are slumping and sediment deposition. Drawdown of the reservoirs to a near-natural condition would expose many formerly inundated sites. Impacts of inundation will be replaced by new impacts including such things as surface erosion, vandalism, and recreation impacts.

Within the zone of fluctuation, the predominant impact is erosion from the mechanical effects of wind, ice and water motion; waves, currents, and water level changes. The zone of fluctuation is also subject to biochemical and human-caused impact, both of which produce widely varying degrees of adverse effects. This zone is where geomorphic processes are most active and where these processes cause the most impact on cultural resources. The erosional geomorphic processes that predominate in the zone of fluctuation include mass wasting, sheetwash, channeled flow, wave wash, ice gouging, and deflation (wind erosion). Depositional geomorphic processes active in this zone include mass wasting (mostly in the form of bank caving and sloughing), fluvial deposition from tributary streams and, when the pool is elevated, sediment deposition from the reservoir. Airborne deposition is also an important sedimentary process in the fluctuation zones of the projects located on the Columbia Plateau.

The zone of indirect impact lies above the normal high water line. It is variable in extent and is primarily affected by susceptibility of the soils to erosion and mechanical impacts stemming from human use of the land. This zone is often overlooked when considering operational strategies because it is seldom or never in direct contact with the pool. However, reservoir levels directly

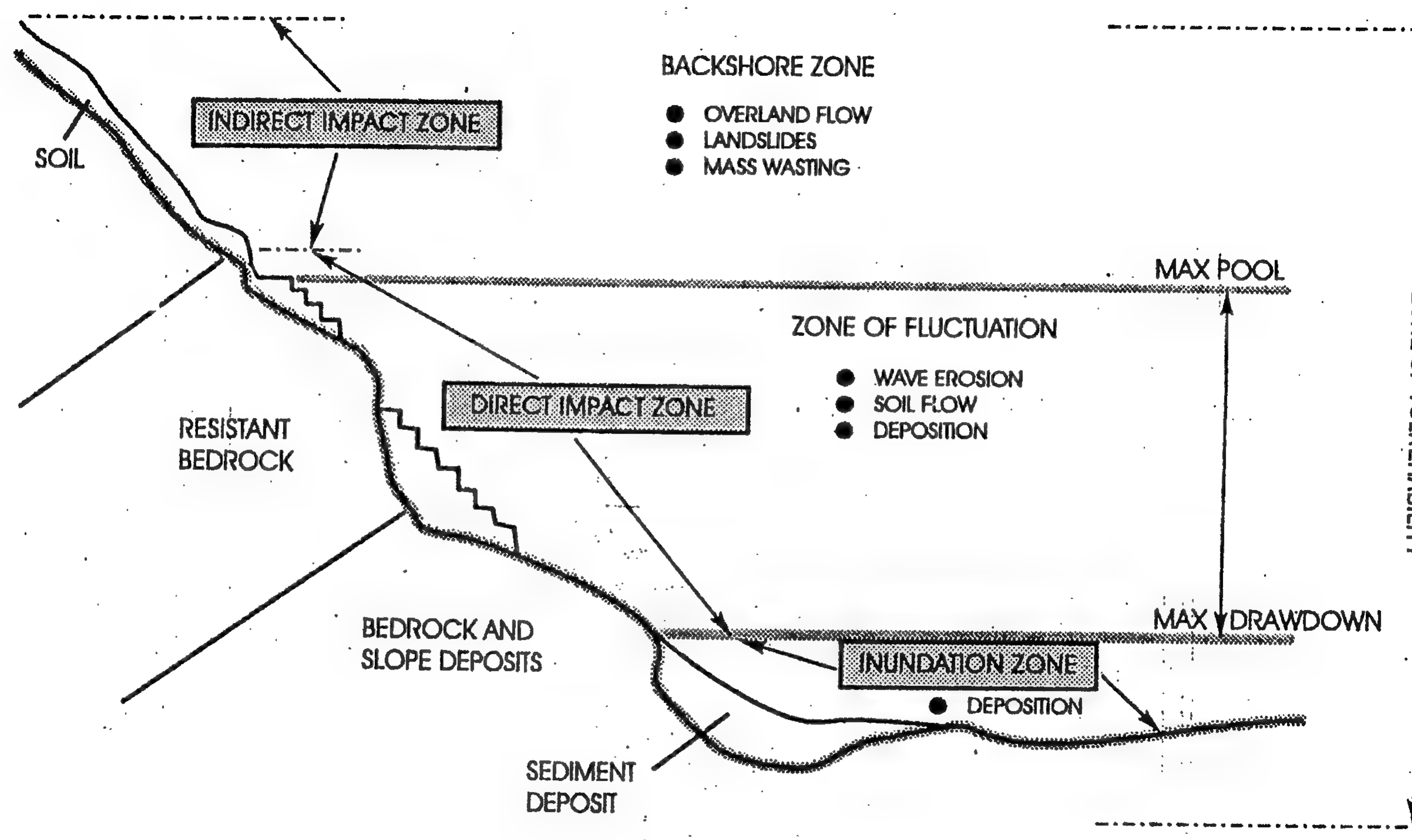


Figure 3-4. Geomorphic Zones found in a Typical Storage Reservoir

Source: SOR FEIS, Appendix D, Figure 3-1

influence such things as human access to the zone, stability of backshore soils, groundwater fluctuations, and biological composition. Sediment issuing from this zone makes a major contribution to the total sediment load entering the reservoir. Erosion is the primary geomorphic process acting in the indirect impact zone. The adverse effects are mostly from mass wasting, sheetwash, channeled flow, and direct rainfall impact, although erosion susceptibility factors condition the degree to which these processes affect cultural resources.

The Dam Breaching alternative would increase the size of the indirect impact zone significantly. Land currently within the impact zone would be added to from the present high water line down to the new "river's edge zone." The reservoir fluctuation zone would be removed and the new impact zone established. This stems from the host of short-and long-term effects known from studies of free-flowing behaviors (i.e., cultural resources susceptible to flood events, river bank erosion, and river bed course changes could expose archeological sites to potentially adverse conditions). However, the primary impacts to cultural resources could likely be focused along the river's edge zone where erosive forces are expected to be less than those now experienced along the reservoir's zone of fluctuation.

3.7 Susceptibility to Erosion

A soil's susceptibility to erosion depends on several factors. These include precipitation effects, soil types, slope, topography, vegetative cover, and erosion control practices (Buckman, 1969). Of course, each of these factors varies throughout each of the lower Snake River project reservoirs' and the impact zones for cultural resources such that, for this study, only the large-scale aspect of erosion susceptibility is considered. Soil scientists have determined characteristic responses to erosion processes and customarily report these responses as part of all soil surveys that are conducted. In terms of large-scale considerations, the single most important erodibility factor to address is the soil texture. Soil properties such as texture can be used to determine whether a soil type is susceptible to transport by forces like wind, water, or temperature extremes.

Soil types and landforms differ in their susceptibility to erosion at the various hydropower facility reservoirs. Generally speaking, soils of the Columbia Basalt Plain region, on which the lower Snake River hydropower facilities are located, are derived from glacier and flood deposits. They are light soils, highly susceptible to erosion by water and wind. The lower Snake River projects have steep slopes that are somewhat susceptible to slumping and land slides.

Shoreline equilibrium is another important concept applicable to the geomorphic analysis. Under consistent operating conditions, and where soils are less susceptible to erosion, reservoir shorelines can reach a state under which further erosion and sedimentation are stable or nearly stable. By the time this happens, cultural resources in the stable shore zone will have been largely destroyed. If the reservoir stays at or returns to this level, however, the erosion of nearby areas can slow. If reservoir operations establish a new stable stand, the shoreline equilibrium can be upset and major new impacts can occur.

It is unknown what level of impact has occurred at most of the inundated sites. The establishment of a new unimpounded river level would result in some new impacts, which could include movement of sediments deposited during the reservoir period. Shoreline equilibrium after return to unimpounded river levels could take some time.

Several factors account for the shoreline equilibrium state. Waves will cut benches through softer soils to bedrock, for example, after which erosion of the bedrock occurs at a much slower pace than before. As waves dissolve finer and looser soil elements, heavier and less transportable rock pieces accumulate on the shoreline. These eventually armor the underlying softer soil from wave action, slowing erosion considerably.

Shorelines can also reach a point of equilibrium due to the completion of slope failure cycles. Due to the repeated action of on-shore waves, a stable reservoir shoreline will begin to cut a bench or notch in a hill slope. Depending on the strength of the shoreline soil material, wave erosion may cut a vertical bank. In clayey or gravelly soils, this bank may reach tens of meters in height. At some point, continued erosion at the slope's toe or loss of stability due to groundwater pressures may cause this cut-bank to fail. This may also occur due to drawdowns, such as the kind conducted in 1992 for the lower Snake River system dams, when water held within the soil mass weighs down the soil in the bank, causing it to slump into the reservoir. These failures produce spectacular slides, mudflows, and slumps along reservoir shorelines. Groundwater flow can also cause these slope failures. Cultural resources located on slumping landforms are often destroyed.

A similar erosion mechanism found along the reservoir shorelines is the landslide. This can occur especially in areas with steeply sloping bedrock and shallow soils. In such places, groundwater flow between soil and rock can exert enough pressure to lift the soil away from the rock surface. This can occur where waves have cut a notch or bench at the bottom of the slope, removing the slope's supporting base. Landslides are often set off by rainfall or snow melt which saturates soil slopes, raising their water pressure. Hill slopes in a reservoir drawdown zone are particularly susceptible to land slides because they are devoid of vegetation that would otherwise help to hold the soil mass together.

A wave-cut bank may never develop in silts, sands, or other low-strength soils because the soil materials do not possess sufficient strength to support vertical banks. In these cases, wide, gently sloping beaches form along the bank. Such soils are particularly susceptible to internal erosion processes, such as piping, that are especially aggravated by rapid reservoir fluctuations. Irregular ground, potholes, linear ridges, and depressions along the reservoir shorelines are characteristic of such soils. Fluctuations and rapid reservoir drawdowns can cause the buildup of high fluid pressures within the soil pores. When the reservoir level drops, the soil releases this water rapidly, resulting in small-scale slumping, piping, and wasting.

Sheet erosion is another problem that can become serious under some conditions. In non-vegetated reservoir draw down zones, runoff from rainfall can concentrate in rills and gullies on long or steep slopes. Run-of-river reservoirs generally do not develop this type of erosion, since they never have substantial areas of exposed reservoir slopes, and exposed slope lengths are short. The free-flowing alternative would result in large temporarily non-vegetated zones.

A small percentage of reservoir erosion is directly anthropogenic (human-caused). Boat wakes and dredging cause minor and generally localized erosion. In some locales, road cuts and side-cast fills have become erosion sites when shorelines impinge upon them, although these are generally stabilized and repaired.

3.8 Impacts of Depositional Process

In the permanently inundated reservoir zones, deposition processes predominate in mechanical impacts to cultural sites. Reservoir sedimentation rates vary depending on the geology and climate of the reservoir watershed. Nevertheless, in all reservoirs, sedimentation is an inexorable process.

In general, post-impoundment sedimentation tends to enhance cultural resource preservation by providing a sediment buffer against mechanical impacts. However, cultural resources buried under a deep silt and water column are no longer accessible for research, or vandalism. Little is known about the long-term impacts of deep sediment burial on fragile cultural deposits. In addition, two processes in the reservoir offshore may be of concern to cultural resource managers: reservoir silt deposit impacts to deeply buried cultural sites, and changes in basin morphology resulting from sediment saturation, slumping, and creep.

There have been no definitive studies of the impacts of heavy silt deposit on cultural deposits; the effects, for example, of weight load, soil saturation and movement, etc., are not known at this time. However, it is only prudent to assume that these processes may result in some adverse impacts to fragile cultural remains. Underwater landslides and sediment shifts are known to occur in the permanently inundated zones of reservoirs (Ware, 1989).

Exposure of formerly inundated by significant sediment load accumulations will result in different mechanical impacts. These will include renewed erosive impacts, possible accelerated slumping and more frequent landslides, and possible biochemical changes in soils. Some benefits, however, may exist from accumulated sediment loads over newly exposed cultural sites. If accumulated sediment can be kept in place using counter-erosion techniques, such sediment loads will tend to protect the integrity of a cultural deposit. Establishment of a permanent native vegetation cover on sites, re-contouring adjacent site soils, and/or applying a layer of rock materials over unstable site areas may be effective means for limiting soil movement, or loss to a site's integrity.

3.9 Reservoir Operations and Impacts to Cultural Resources

3.9.1 Impacts to National Register Sites and Districts

All of the sites and districts in the study area currently listed on the NRHP are affected in some way by reservoir operation. Many of these sites and districts have portions located within reservoir pool drawdown zones or below current minimum water levels. Others are located in or near shoreline recreation areas and are subject to vandalism and theft.

Many other cultural resources at the projects are potentially eligible for National Register nomination, but have not been thoroughly evaluated or nominated. Many of the lower Snake River sites are experiencing ongoing loss of integrity, an important element of NHPA significance, due to the effects of reservoir level fluctuations, recreational activities, and natural weathering processes.

3.9.2 Impacts on Cultural Resources in the Current River Fluctuation Zone Under the First Three Alternatives

Shoreline erosion within the current drawdown zone is a very serious impact to cultural resources on the lower Snake River. Within the shoreline fluctuation zone of most man-made reservoirs, virtually all categories of impacts to cultural resources are magnified, with mechanical hydrological impacts constituting the greatest threat to cultural resources. Wave action poses the most serious threat in

the reservoir fluctuation zone. Important variables include wave approach, wave intensity, and shoreline geomorphology. The interaction of these variables will determine the formation and configuration of the shoreline and the high-energy beach zone.

Fluctuating pool levels enlarge the zone of destructive wave action by increasing the effective beach zone of a reservoir. As the reservoir pool level draws down, breaking waves strike the saturated and unconsolidated elements of the reservoir basin that have already been deprived of a protective vegetative cover. These fragile sediments are susceptible not only to wave erosion but also to subsequent wind and water runoff erosion within the exposed drawdown zone (Lenihan et al., 1981).

Whereas very little is known about impacts to cultural resources within the permanently inundated reservoir zones, a great deal of comparative data are available on shoreline impacts, in part because sites that are periodically exposed are more accessible to scrutiny. Archaeological surveys of drawdown zones indicate that waves and near shore currents can dislodge and displace large artifacts. Extensive impacts to architectural features and archaeological midden deposits have also been reported. At Wister Reservoir in Oklahoma, several prehistoric midden sites were virtually leveled by shoreline wave erosion (Galm, 1978). Similar effects have been observed at reservoirs throughout North America (Lenihan et al., 1981). Although only about 25 percent of the lower Snake River reservoirs resemble reservoir geomorphology conditions found at Wister Reservoir, the study area may be more predisposed to such cultural resources impacts given its typically steeper terrain.

Although mechanical impacts predominate in the reservoir fluctuation zone, the potential for biochemical and human impacts on the shorelines of reservoirs is greater than in any other reservoir zone. Biochemical activity is accelerated in the shallow waters of the reservoir littoral zone because of higher light, dissolved oxygen levels, and ambient temperatures. These conditions will support more organisms that may degrade perishable cultural materials. Similarly, the potential for human and animal impacts is greater in the shoreline fluctuation zone than in any other reservoir zone. Reservoir environment recreation and all its attendant impacts are concentrated at the reservoir shoreline: boat ramps, swimming beaches, campgrounds, recreational vehicles, power boats, and their destructive wakes are all potential sources of adverse impacts to fragile cultural resources.

As human use and visitation of the lake shore increases, vandalism invariably increases. Since native vegetation is often deflated along the periodically inundated shoreline, cultural resources are often highly visible and more susceptible to human impact.

Sites not subject to reservoir conditions may still be subjected to a wide range of adverse effects, depending on local circumstances and human activities. In some places, surface erosion due to wind and runoff is very serious; in others, it is not. Similarly, some sites are very accessible to the public and experience vandalism when exposed, and others are less accessible or more difficult to detect. By contrast, shoreline erosion constantly eats away at sites where it occurs.

3.9.3 Impacts on the Reservoir Backshore Under All Proposed Alternatives

The reservoir backshore is the area above the level of the maximum reservoir pool in the case of an operating reservoir, or above maximum high water in the case of a naturally flowing river. It extends upstream and upslope to include much of the reservoir watershed. There are no direct mechanical or biochemical impacts in the reservoir backshore caused by reservoir operation. But,

other impacts can be anticipated that are directly related to reservoir construction and use. Reservoir construction and use results in increased access to a complete watershed, making previously inaccessible areas readily accessible to anyone with a boat and an inclination to explore. A marked increase in cultural resource vandalism accompanies the construction of a new reservoir, and destructive changes in watershed land use may further degrade cultural resources.

In addition to outright vandalism, changes in land use following reservoir impoundment can have adverse impacts on cultural resources. The reservoir backshore attracts picnic areas, campgrounds, hiking and riding trails, new roads, boat ramps, and parking lots. Many of these developments would follow the return of a reservoir to a river level as well, in the newly exposed backshore areas.

The impacts of domestic livestock pose additional threats to fragile cultural resources. Increases in livestock grazing following freshwater impoundment may have a serious impact on backshore resources: cattle trampling breaks up artifacts on the ground surface: cattle also topple standing walls, wallow in the soft soil of trash middens, and destroy the fragile stratigraphy of rockshelters. Changes in livestock use of newly exposed backshore areas following a return to unimpounded river levels should exclude livestock impacts. The existing corridors through which livestock have been allowed to reach the reservoirs over Corps property for watering would be removed, and mitigation explored concerning alternate water sources on livestock owners' land.

3.9.4 Impacts on Cultural Resources Between Current Reservoir Natural Operating Levels and Unimpounded Levels Which Would be Exposed by the Dam Breaching Alternative

The proposed Dam Breaching alternative would cause a higher rate of site exposure than the other alternatives. The current set of cultural resource management issues for the project would in large part be exchanged for another set. Significant impacts to sites may result under the current proposed 2-foot-per-day drawdown rate of reservoirs across a broad range of soil types and landforms (Center for Northwest Anthropology, 1992). This rate could be too rapid for many sites in the direct impact and inundation zones of reservoirs and could cause losses to the integrity of potentially significant cultural deposits. Potential effects on newly exposed sites in this reservoir system would include vandalism, theft, surface erosion, slumping along river banks and hill slopes, lateral displacement, trampling/wallowing by hoofed animals, rodent burrowing, climatic/precipitation cycles, and biochemical soil changes.

Water flow events, caused by spring upland releases, or flow augmentation for anadromous fish runs are expected to have no greater effects than current reservoir fluctuation impacts. Effects would be re-focused to the meandering zone of the river course, typically along the river edge. In the Dam Breaching alternative, short and long-term river behaviors will re-expose sites to periodic flood events, and river movements that alter terrace structures and river bed channel locations. Such river movements could occur within the limits of the lower Snake River's near-natural meander zones, which generally are expected to be at lower elevations than the current reservoirs' fluctuation zone. Some sites and portions of sites could be re-exposed with an overlying sediment load of variable thickness due to 20 to 40 years of reservoir inundation conditions. Consequently, sites in these circumstances could remain partially or prohibitively inaccessible. While difficult to fully anticipate, new uses of the unimpounded system from recreational, cultural, and agency administration standpoints could still occur under existing Federal law and policy directives. If the

lower Snake River became a significant destination site for recreation, resource protection and public education would necessarily be emphasized.

Many of this alternative's most significant impacts to sites would be temporary. Although most known archaeological sites would be exposed in a non-vegetated zone following the reservoir breaching, in time, the reservoir landscape would be re-vegetated and other site protective measures established. Benefits to most reservoir resources would include their renewed access for scientific research, cultural resource management operations (e.g., site evaluations, NRHP nominations, site protection data recovery), and traditional cultural practices. Site protection by more aggressive measures could be needed at selected sites. Protective structures can be constructed at sites having special circumstances.

If we can assume the culmination of effects for inundated cultural resources and shoreline erosion to sites is often worse than site exposure, we may also assume that alternatives that increase site exposure might be best for the resource. Dam Breaching would remove the previously constant effects of shoreline erosion at these reservoirs in exchange for riverine behaviors within its meander/flood zones. The net effect on cultural and historic properties may indeed be positive. However, a cultural resource management plan with aggressive resource treatments and preservation strategies would need to be implemented.

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4. Development of a Cultural Resources Management Program

4.1 Program Coordination with Consulting Parties

Development of a comprehensive resource management strategy requires that the Corps gather as much information as possible about the nature and condition of the cultural and historic properties located on its lands. To assist with this endeavor, the Corps is participating in the Payos Kuus Cuukwe cooperating group that was formed out of the Federal Columbia River Power System Cooperative Group study. The group's focus is to address cultural resources issues collaboratively with affected Indian tribes and to help meet Federal compliance responsibilities for cultural resources protection and management.

Information gathered through cultural resources projects will enable the Corps to develop appropriate management plans. Final selection of the preferred alternative for the feasibility study will determine the nature and extent of cultural resources tasks needed to address the selected alternative.

4.2 Cultural Resource Management Strategy

Federal responsibilities to consider cultural resources include required site inventories of Federal lands, determinations of sites' NRHP eligibility, and assessment of effects under proposed agency activities. There is a wide range of management strategies available to preserve cultural resources and to mitigate natural and human effects to potentially/eligible cultural resources. These include educating the public on the importance of cultural resources; inclusion of cultural resources needs into Federal law enforcement programs; resource inventories and monitoring, site condition assessments, restoration and data recovery of potentially eligible sites.

Under the three different feasibility study alternative pathways, cultural resources management would continue largely as it exists except under the third pathway. In the Dam Breaching alternative, cultural resources management responses would address newly exposed lands and resources as a special circumstance with many unknowns as to site locations, conditions, and preservation needs. An assertive educational strategy intended to inform the public of cultural resources values and vulnerabilities, and one which interprets the Snake River's cultural history would help protect exposed resources until they can be fully protected by physical or vegetation cover remedies. An aggressive law enforcement policy would be necessary to check site vandalism and thefts. It is anticipated that current levels of site vandalism and theft would increase and an aggressive law enforcement response would best curb any such negative trends. A comprehensive resources inventory to identify and assess resource conditions would be necessary to manage the lower Snake River. Where NHRP eligible and nominated resources are imperiled, cultural resources data recovery and mitigation strategies would be readily implemented. Also, a protection plan involving a variety of physical remedies would be employed to preserve sites from a host of potential adverse effects resulting from a dam breaching.

4.3 The Cultural Resources Protection Plan

The Federal responsibility to protect and preserve cultural properties under the implementation of the proposed alternative management actions can be met by developing and carrying out an effective management plan. The cultural, historic, and scientific importance of cultural sites can be preserved by various physical means. The engineering aspects for physical protection of cultural resources are discussed in Annex N of Appendix D, Natural River Drawdown Engineering.

Following are measures other than site armoring, which can preserve the significance of cultural properties. It must be understood that all site management and protection measures are not appropriate for all cultural sites. The cultural and scientific significance of individual sites must be considered in order to apply effective management and protection measures.

4.3.1 Cultural Resources Monitoring

To beneficially manage cultural resources, the responsible agency must gather information about the condition of cultural properties and the change in condition due to various impacts over time. Site monitoring is the critical mechanism that provides this information.

To effectively monitor impacts to cultural resources, the monitoring effort must follow a thoughtfully designed monitoring plan. This plan would be developed by the responsible Federal agency in cooperation with regional Indian tribes and various interested parties.

Site monitoring is a key means by which the Corps can manage cultural resources. Proper monitoring describes site conditions and documents impacts or changes to cultural resources sites over time, which can assist in the development of appropriate protection measures. Site observation and protection are directed specifically to areas of erosion impact, such as stream banks and areas prone to vandalism. Such information would be useful in resource protection and evaluations of sites (i.e., eligibility to the NRHP, resource planning, ARPA compliance, and archaeological investigations). Site evaluations or archaeological investigation is not part of site monitoring.

The Corps would oversee all cultural resources monitoring. Documentation would include written and photographic information and data entry into the Walla Walla District's cultural resource database.

4.3.2 Mitigation or Treatment of Affected Cultural Resources

The usual subjects of CRM mitigation or treatment are National Register eligible sites threatened by adverse impacts such as construction, inundation, erosion, or vandalism. Actual treatment measures may vary with each site. Some of the common options include the following: site avoidance; protection; data recovery and curation; and interpretation and use in educational programs. Simple site avoidance is not possible under the proposed alternative pathways since either continued operational practices requiring the fluctuation of reservoir levels, or permanent dam breaching would affect the integrity of cultural resources. Site protection would be necessary under all the alternatives, however, there would be a tradeoff as to what sites would require protection and the nature of protective measures. For example, many sites subject to the effects of fluctuating reservoir levels often require protective barriers against water action in order to prevent the loss of significant cultural resource deposits contained in site soils. If reservoir levels were drawn down, such sites may no longer require protective barriers but instead might need increased law enforcement protection for the short term.

4.3.3 Avoidance or Protection

Federal agencies should plan projects in order to avoid impacts to cultural resources. Only as a last resort, when destructive effects cannot be avoided, will the agency conduct data recovery. In the case of reservoirs, it is often difficult to avoid impacts to resources. Some measure of protection can, however, be secured by bank stabilization measures, protective levees, covering sites, erecting barriers, or other measures.

If the level of significance is high and geologic and soils conditions are favorable, sites may be protected by stabilization efforts such as site capping, slumpage control, and stream bank stabilization. Site protection also includes intensive management efforts such as signage, public education programs, and law enforcement efforts. It is anticipated that, despite efforts to discourage the public from illegal activities such as surface-collecting artifacts and excavating archaeological sites, sites would still be subject to such adverse impacts, especially during the immediate period after drawdown of any project reservoir. This observation is based upon the results of the 1992 drawdown cultural resource monitoring project that documented effects on a select group of known archaeological sites in Lower Granite and Little Goose reservoirs. Thus, a concerted and comprehensive effort to identify illegal activities and prosecute such offenses would need to be in place prior to actual dam breaching. This would include planning for additional law enforcement, enhanced site monitoring, and an evaluation process.

4.3.4 Data Recovery and Curation

When a significant cultural resource is threatened by loss from erosion, vandalism, or other impacts, scientific data recovery may constitute the only way to document the site's significance and offset the loss. All scientific excavation is conducted under site-specific research plans developed in consultation with appropriate parties (e.g., affected tribes, and state/Federal agencies). A key requirement of the data recovery process involves the curation of recovered materials and the associated documentation in a facility meeting strict Federal guidelines. This is to ensure the preservation in perpetuity of cultural resource collections for their scientific research and educational value. Curation of excavation notes, recovered artifacts, soil samples, and other materials provides research, educational, and interpretation opportunities for the scientific community, local Native American communities, and the public. The retention of current collections in repositories local to the Snake River has proven an asset to professional research interest and contributed to public education.

4.3.5 Native American Graves and Repatriation Act

Native peoples of the Snake River Basin resided primarily along the shores of the Snake River and its tributaries. Villages were located primarily in the lowlands, even though subsistence resources were acquired from both riverine and nearby upland environments. The focus of peoples' lives along the river system meant families most often interred their deceased in these same areas. The cemeteries and burial places of native people from the past 12,000 years are not all known to the Walla Walla District. Consequently, inadvertent discoveries of Native American human remains are not uncommon, and they must be readily cared for to avoid further disturbance by either human or natural agents. Both Corps policy and the Native American Graves and Repatriation Act (NAGPRA) provide direction on how such human remains are treated. Public awareness of how people can help by leaving remains alone and notifying responsible county and Federal agencies is

still needed. The Corps is required to provide for inadvertent discoveries of human remains, regardless of which proposed alternative pathway is selected.

The primary guidance for addressing inadvertent discoveries of human remains is found in the NAGPRA and its implementing regulation, 43 CFR Part 10. Sections 10.4 through 10.6 of the regulation, specifically identify the steps the agency is to follow when dealing with an inadvertent discovery. This includes notification, consultation, and determination of custody. A complete administrative record must be developed and acknowledgement made that the Federal government does not maintain further responsibilities following the transfer of NAGPRA cultural materials to the appropriate tribe(s). Currently there are four tribes and one band that retain interests in the disposition of both inadvertent discoveries and NAGPRA cultural materials that are in local repositories.

4.3.6 Consultation with Indian Tribes

Cultural resources mitigation or treatment efforts undertaken by the Corps will require consultation with affected Indian tribes. Such consultation takes into account the Corps' part in the government-to-government relationship with affected tribes and Federal trust responsibilities to tribes. (See Appendix Q, Tribal Consultation and Coordination of the Lower Snake River Juvenile Salmon Migration Feasibility Study for further information.) Discussions need to include resource management plans (e.g., mitigation measures) that are sensitive to tribal concerns and responsive to mandated scientific data recovery and artifact curation requirements. Affected tribes may participate in direct and meaningful ways. Early and regular contacts with affected tribes in planning and project implementation provides for collaborative cultural resource management efforts.

4.3.7 Coordination with Mitigation Efforts for Other Resources

Mitigation plans will be developed for impacts on a variety of natural resources. These may include resident fish, wildlife, recreation, and others. In some situations cultural resources appear in the same physical context as these other resources or activities. Where such overlaps occur, planners need to consider mitigation efforts so that actions benefiting one resource do not harm another.

5. Summary

The region included in the feasibility study contains rich archaeological, historical, and traditional resources. Any of the proposed study alternatives, if adopted, would all have effects on cultural resources. Measures may be required to avoid or mitigate those effects.

The Dam Breaching alternative is likely to impact cultural resources more intensively than the other alternatives. While of some benefit, in-site preservation might result in re-exposing inundated sites; extensive protection and mitigation activities may be required to preserve the sites' integrity. The first three alternatives would result in no discernable change in conditions compared to current operations.

In the short term, the effects to cultural resources under the Dam Breaching alternative would predictably provide increased impacts to sites, within the reservoir's inundation zone, that lie above the historical natural river course and have not been buried by reservoir sediment deposits. Those sites in the direct impact zone of reservoirs would potentially experience the greatest impacts in the short term under the Dam Breaching alternative due to both natural and human agents. Effects to sites in the reservoir's indirect impact zones are not predicted to experience significantly different impacts from any of the proposed alternatives. This is thought to be the case since reservoirs do not currently impact these sites other than to redirect land-based human activities to these areas to a greater extent than would be expected under dam breaching.

Over the long term, effects to sites in both the direct impact and inundation zones of the reservoirs would predictably experience impacts comparable to those currently in the indirect impact zones. This is based upon both the expected benefits from natural processes (e.g., natural revegetation and lack of reservoir actions upon sites) and cultural resource management actions (e.g., public education and site protection treatments). Sites that have been partially or fully buried by reservoir sediments in either the inundation zone or the direct impact zone predictably would not experience further impacts under the Dam Breaching alternative. In fact, such sites may even benefit if they may become more accessible for management as either natural or resource program activities provide opportunities for re-exposure.

Sites not protected by reservoir sediment deposits in the reservoir direct impact zone may require the greatest attention from resource management to prevent short-term impacts. Conversely, they may exhibit the greatest benefits in the long term as these sites become more available for resource management. This expectation is based on the premise that reservoir actions on sites have greater adverse effects to sites' integrity than either near-natural or managed free-flowing rivers.

Coordination with tribes, SHPOs, and the Advisory Council on Historic Preservation Offices would be a necessary part of managing cultural resources under any of the considered alternatives. Sites and districts already determined eligible for nomination to the NRHP would require particular attention given that the Corps has specified management responsibilities for such resources. Cultural resources mitigation or treatment efforts undertaken by the managing agency require consultation with affected Indian tribes. Such consultation takes into account the Federal agency government-to-government and tribal trust responsibilities. Discussions include mitigation or treatment and management measures that are sensitive to Tribal concerns and responsive to scientific data recovery and curatorial needs and requirements.

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7. Glossary

Aggradation: The deposition of sediment by running water.

Alluvial: Unconsolidated and sorted to semi-sorted material deposited by a stream or other body of running water during relatively recent geologic time.

Altithermal: A middle Holecene interval marked by significantly warmer and drier climatic conditions than the preceding Anathermal interval. This interval lasted from around 8,000-4,000 years B.P.

Anadromous fish: Fish, such as salmon or steelhead trout, that hatch in fresh water, migrate to and mature in the ocean, and return to fresh water as adults to spawn.

Anathermal: An early Holocene climatic interval following the Pleistocene glacial period dating from 14000 to 8000 B.P. Climate was similar to that of today.

Archaeological context: The setting of an artifact or feature in an archaeological site; or, its set of spatial, temporal, and functional relationships to other artifacts and features or the landscape.

Archeological district: A significant concentration of or linkage/continuity between sites, structures, or objects united by common age, spatial proximity and/or archeologically recognizable cultural development, e.g. Palouse Canyon district is a small group of nearby sites of the Cascade time period that exhibit physical evidence of similar tool kits and cultural practices.

Archaeological record: The information that archaeological sites contain about prehistoric and historic lifeways.

Archaeological site: A deposit, construction, or other trace of human behavior, generally greater than 50 years old.

Archaeological survey: A methodical examination of an area in order to detect, map, and record the presence and nature of archaeological sites.

Atlatl: A spear or dart throwing stick which extends the arm and increases the velocity of the thrown projectile.

Augmentation: Shaping and volume regulation of river flow as affected by hydropower facilities up river from the Lower Snake River Project area in order to support out going anadromous fish runs on their journey to the ocean.

Backflooding: Flood water flowing upstream from a tributary of a stream or from a cataclysmic flood.

Biface: An artifact, especially stone, which is worked on two sides (such as a lance point or a projectile point).

B.P.: Before Present. Indicates the age of material dated using the Carbon-14 dating method. Such dates may be converted to the Christian calendircal references of B.C. and A.D.

Cataclysmic floods: Floods of magnitude greater than that known during historic times. Cataclysmic floods occurred during the glacial epoch when ice dams impounding very large lakes broke, releasing very large volumes of water into the Columbia Basin.

Cordilleran Ice Sheet: A large glacial period ice sheet that covered much of the Interior Northwest between the Canadian Cascade and Rocky Mountain ranges. Its southern most extent (Okanogan lobe) was located near the latitude of Waterville, Washington.

Cultural resources: Archaeological and historical sites, historic architecture and engineering, and traditional cultural properties.

Cultural Significance: The whole set of relationships, understood and defined by a group of people through their culture, concerning their world including landscapes, places, and both living and inanimate things.

Cultural site: A property of archaeological, historic, or cultural significance.

Curation: The cataloging, storage, and preservation of artifacts and other archaeological or historic materials.

Depositional processes: Processes that create and transform archaeological or geological deposits.

Drawdown: To lower the elevation of a reservoir by releasing water at a rate faster than inflow.

Edgeground: A tool worked along one or more edges. Usually an abraded surface formed while using a tool for its intended purpose rather than during its manufacture.

Erosional process: Processes such as landslide and sheetwash, that change landforms by reshaping them, wearing them away, or destroying them.

Exposure (of a natural resource): Making an archaeological, historic, or traditional cultural property vulnerable to erosion or vandalism; for example, by lowering a reservoir water level to uncover an archaeological site.

Geomorphic/geomorphological: Having to do with landforms and the forces that change them.

Historic period/era: The period of time for which written records exist of a place. For example; the lower Snake River after 1805 with the arrival of Lewis and Clark's Corps of Discovery.

Historic property: An archaeological, historic, or traditional cultural property.

Historic resource: A cultural resource or a property belonging to a time and place for which written records are available.

Holocene: The recent epoch of geological time directly following the last glacial period known as the Late Pleistocene. Dates from about 9000 years B.P. to the present.

Housepit: Semi-subterranean house structure with the lower few feet usually set slightly into the ground. Typically, wood beam frame and central post construction with an earthen super-structure. Entry into structure from top side using a log step ladder.

Hypsithermal: A post-pleistocene glacial interval that lasted from 9000-2500 years B.P. Mean average temperatures during this time were above those of modern times.

Interbedded: The state of being stratified among or between other strata.

Lanceolate: Shaped like a lance point. Narrow and gradually tapering toward the tip.

Lithic: Of stone. Usually, in archaeology, defining a stone artifact or tool.

Lithic quarries: Places where people collected or mined stone suitable for toolmaking.

Littoral Zone: The shore area along a body of water, usually a lake, down to the depth of 10 meters.

Loess: A fine unconsolidated wind blown sediment, typically silt.

Lower Snake River Project (LSRP): The four multi-purpose facilities operated by the Corps as a unit on the lower Snake River. The facilities include Ice Harbor Lock and Dam (Lake Sacajawea), Lower Monumental Lock and Dam (Lake West), Little Goose Lock and Dam (Lake Bryan), and Lower Granite Lock and Dam (Lower Granite Lake).

Mano: The grinding or lower surface of a mano and metate. The mortar of a mortar and pestle.

Midden: A refuse heap.

Mitigation: To moderate or compensate for an impact or effect.

National Register of Historic Places (NRHP): A list of historic properties of local, regional, and national significance.

Paleoindian: Term for the oldest (as determined by scientific evidence) human occupants of the American Continent.

Paleontology: The study of prehistoric forms of life through the study of plant and animal fossils.

Paleosols: Fossil or very ancient sediment deposits.

Petroglyphs/pictographs: (also "rock art") Carvings or paintings on rocks, especially those made by prehistoric people.

Physiography: Physical geography

Pleistocene: The Pleistocene epoch, characterized by the rise and recession of the continental ice sheets and the appearance of humanity.

Pool: Reservoir, a body of water impounded by a dam.

Radiocarbon assay: The date or age determined by measuring the decay of carbon isotopes in an archaeological sample.

Reconnaissance: An inspection or exploration.

Rock shelters: Natural shelters located under rock overhangs.

Sahaptian: A Native American language family that includes the Nez Perce and Sahaptin languages.

Sahaptin: Native American language with 14 known dialects, which fall under three dialect divisions: Northwest, Northeast and Columbia River. Native Sahaptin speakers who once lived in the LSRP area spoke the dialects classed under the Northeast dialect division.

Salmonids: A family of anadromous and resident fish that includes Chinook and whitefish.

Saturated soil: Soil, the pores of which are at or near their maximum water capacity.

Scablands: The Channeled Scablands of eastern Washington state eroded by cataclysmic flood events.

Slumping: A landslide; the separation of a land or soil mass from a land surface and its movement downslope.

Strata: A layer of rock or sediment of a given age and type.

Stratagraphic: Pertaining to soil strata.

Temporal: Pertaining to time.

Tephra: Greek for ashes. In archaeology; volcanic ashes, usually deposited in a layer among the strata of an archaeological site. A useful indicator of the relative age of cultural deposits.

Terrace: A flat, narrow stretch of ground often having a steep slope facing a river, lake, or sea.

Thermal Maximum: Same as Altithermal, a middle period post-glacial climatic interval.

Traditional cultural properties: A cultural resource having significance for its association with cultural practices or beliefs of a living community that are: a) rooted in the community's history, and b) important in maintaining the cultural identity of the community.

Turbidity: The state or quantity of being turbid; having the sediment stirred up, muddy, cloudy.

Wet and dry cycle exposure: The exposure of archaeological deposits or other items to repeated wetting and drying, causing physical deterioration.

Zone of fluctuation: The area extending between high water level to low water level of a reservoir.

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Appendix O
Public Outreach Program

February 2002

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Appendix O
Public Outreach Program

Produced by

U.S. Army Corps of Engineers
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February 2002

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FOREWORD

Appendix O was written by the staff at U.S. Army Corps of Engineers (Corps), Walla Walla District. This appendix is one part of the overall effort of the Corps to prepare the Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement (FR/EIS).

The Corps has reached out to regional stakeholders (Federal agencies, tribes, states, local governmental entities, organizations, and individuals) during the development of the FR/EIS and appendices. This effort resulted in many of these regional stakeholders providing input and comments, and even drafting work products or portions of these documents. This regional input provided the Corps with an insight and perspective not found in previous processes. A great deal of this information was subsequently included in the FR/EIS and appendices; therefore, not all of the opinions and/or findings herein may reflect the official policy or position of the Corps.

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ACRONYMS AND ABBREVIATIONS

BGS	behavioral guidance structure
Corps	U.S. Army Corps of Engineers
DREW	Drawdown Regional Economic Workgroup
Feasibility Study	Lower Snake River Juvenile Salmon Migration Feasibility Study
FR/EIS	Lower Snake River Juvenile Salmon Migration Feasibility Report/ Environmental Impact Statement
PATH	Plan for Analyzing and Testing Hypotheses
SBC	surface bypass collector

ENGLISH TO METRIC CONVERSION FACTORS

To Convert From	To	Multiply By
LENGTH CONVERSIONS:		
Inches	Millimeters	25.4
Feet	Meters	0.3048
Miles	Kilometers	1.6093
AREA CONVERSIONS:		
Acres	Hectares	0.4047
Acres	Square meters	4047
Square Miles	Square kilometers	2.590
VOLUME CONVERSIONS:		
Gallons	Cubic meters	0.003785
Cubic yards	Cubic meters	0.7646
Acre-feet	Hectare-meters	0.1234
Acre-feet	Cubic meters	1234
OTHER CONVERSIONS:		
Feet/mile	Meters/kilometer	0.1894
Tons	Kilograms	907.2
Tons/square mile	Kilograms/square kilometer	350.2703
Cubic feet/second	Cubic meters/sec	0.02832
Degrees Fahrenheit	Degrees Celsius	(Deg F –32) x (5/9)

Executive Summary

The U.S. Army Corps of Engineers (Corps) developed the Public Outreach Program to raise and promote involvement in the Lower Snake River Juvenile Salmon Migration Feasibility Study (Feasibility Study). The program began with public scoping meetings in 1995 and has continued throughout the Feasibility Study. The information presented in this appendix will provide specific details about the Public Outreach Program as well as public participation levels.

The objectives of the program are to raise awareness and understanding, create opportunities for involvement, and motivate the publics to contribute to the Feasibility Study. To meet these objectives, a variety of informational and involvement techniques have been established to reach the public.

Techniques used to convey study information and processes involved the following media:

- informational video
- web site
- mailing list
- newsletters
- traveling displays
- brochure
- information sheets
- information packets
- news releases
- media broadcasts
- newspaper inserts
- media events.

Public involvement techniques included:

- information meetings
- workshops
- community assessment forums
- briefings
- tours
- speaking engagements
- personal communications.

Formal public meetings were conducted throughout the region to provide opportunities for the public to comment on the Draft Lower Snake River Juvenile Salmon Migration Feasibility Report/ Environmental Impact Statement.

The audiences that participated in public outreach efforts included, but were not limited to, stakeholders, elected officials, media, academia, and governmental agencies. For the purposes of this study, outreach efforts for tribal representatives are documented and discussed in Appendix Q—Tribal Consultation and Coordination.

Monitoring the effectiveness of public outreach programs has been accomplished through video feedback forms, community comment cards, and web site analysis.

Thousands of residents throughout the region have participated in meetings, workshops, and forums about the study and continue to closely follow the process. National as well as international interest in the Corps web site has taken outreach to a new dimension in information dissemination. Feasibility Study team members have made every reasonable effort to provide an open and effective public outreach effort. From the outset, the outreach program has made extraordinary efforts to facilitate the public's opportunity to understand the study and to become involved in the process.

1. Introduction

The U.S. Army Corps of Engineers (Corps) has conducted an aggressive outreach effort throughout the Lower Snake River Juvenile Salmon Migration Feasibility Study (Feasibility Study) process, in order to both raise awareness and promote involvement. Public interest in the Feasibility Study has been high, and continual communication has been essential because the impacts could be far reaching. The public outreach program began with scoping meetings in 1995 and intensified in 1997 with the implementation of the Public Outreach Plan.

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2. Strategic Approaches

Developing an effective public outreach process for the Lower Snake River Juvenile Salmon Migration Feasibility Study (Feasibility Study) has been challenging due to the variety of salmon-related projects already underway or being planned, the duration of the study, the technical nature of the alternatives, and the typical structured nature of the planning process. To meet these challenges, the Corps has focused on conveying four strategic messages to inform the public of the Feasibility Study's relevance and immediacy:

- Lower Snake River salmon stocks are in danger, and four alternatives have been identified to help evaluate options for improving their migration through the lower Snake River.

  The Corps' goal is to inform all audiences about the purpose of the Feasibility Study and the four alternatives under consideration. If individuals are exposed to a consistent message from a variety of sources, the potential is higher for generating interest in that message. In all public outreach efforts, the Corps has emphasized that a primary goal of the Feasibility Study is to provide to the public, stakeholders, and decisionmakers the information on proposed alternatives for improving the conditions for juvenile salmon as they migrate downstream to the ocean.

- The decision about the improvement of salmon passage on the lower Snake River is a national issue with significant regional impacts.

  The Corps has emphasized that the changes to the lower Snake River considered in the Feasibility Study will have substantial regional effects. The decisions resulting from this study could shape the physical landscape, natural environment, economic life, and recreational opportunities available to the people of the Pacific Northwest for generations to come. Public outreach materials and activities have communicated that people throughout the region have a stake in how the lower Snake River is used and that everyone will share in the benefits and costs resulting from the decision that follows the study. While efforts to inform and involve the public have focussed on those most likely to be affected, all inhabitants of the Pacific Northwest will have an opportunity to learn about and provide comments on the Feasibility Study.

- The decision about the improvement of salmon passage on the lower Snake River will personally affect people.

  The Corps has encouraged the public to consider how the choices in the Feasibility Study will personally affect them and their families in both the present and the future.

- The decision about the improvement of salmon passage on the lower Snake River relates to other decisions about salmon and river use in the Northwest.

  The Corps has demonstrated how this study is related to other efforts in the Columbia/Snake River Basin. Possible impacts of decisions resulting from the Feasibility Study on other initiatives have been stressed to underscore the importance of this study to members of the general public.

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3. Public Outreach Plan

The Public Outreach Plan was developed through a cooperative effort involving study management, technical, and public involvement staff from the Corps; and contractor staff specializing in environmental compliance, communications, social science, and public involvement. The plan is based, in part, on current and recent public outreach efforts conducted for similar types of studies, as well as on the collective knowledge and experience of those responsible for drafting the plan. In addition, the plan reflects insights gained through telephone interviews with individuals from a variety of Federal agencies, as well as sources representing state agencies, environmental groups, and river user interests in the Pacific Northwest. Those interviewed were asked what the key issues and concerns for the project are, how people obtain information about salmon and river use matters, who would be interested in the study, and what approaches might work best for communicating with interested parties.

3.1 Outreach Plan Goal and Objectives

The goal of outreach has been to inform and involve people in the region in the engineering, science, and planning process that will lead to a recommendation on the future operation for fish passage at the Lower Snake River Hydropower Project. Everyone benefits when the public is informed and involved. Individuals and groups can ensure that their perspective is heard and factored into the decisions made, and the Corps ensures that it has considered all the factors and recommended a plan that has full public involvement. This outreach program supports the Corps, cooperating agencies, and the public in working openly and collaboratively toward a recommendation that can be effectively implemented. Specifically, the goals outlined in the Public Outreach Plan are to:

1. Raise awareness and understanding by informing people about the Feasibility Study
2. Create opportunities for people to be involved in the science, engineering, and planning process of the Feasibility Study
3. Motivate cooperating agencies, stakeholders, and the public as partners in contributing their perspective and expertise to this endeavor.

3.2 Audiences and Participants

Public outreach efforts for the Feasibility Study have engaged the public in two ways. When the outreach has taken the form of information, those involved have been an audience. When the outreach has taken the form of involvement, those involved have been participants.

The outreach effort has focussed on a broad public, as well as specific involved and interested parties. The following list includes broad groups where outreach efforts have taken place:

- General public
- Stakeholders
- Elected officials
- Native American Tribes (See Appendix Q—Tribal Consultation and Coordination)

- Media
- Academia
- Governments
- Agencies
- Government forums.

4. Information Techniques

The Corps has worked to raise awareness through a multimedia, multitechnique information campaign. Public information is one-way information, with little or no opportunity for feedback. The purpose of raising awareness is to minimize or eliminate any surprises for decisionmakers or the public about the decision regarding the future of the lower Snake River. Those interviewed consistently and forcefully said that the Corps' greatest challenge will be making the public aware of the Feasibility Study. Consequently, much of the public outreach effort has been focussed on raising awareness about the existence, purpose, and process of the Feasibility Study. Public informational efforts are a necessary foundation for public involvement efforts. The following sections describe the public information techniques the Corps has used.

4.1 Informational Video

A 13½ minute video, *The Path of the Salmon*, was produced to convey a consistent message to inform the varying publics of the Lower Snake River Juvenile Salmon Migration Feasibility Study. The *Path of the Salmon* captures the highlights of the current controversy over the plight of the salmon in the lower Snake River. It gives a brief history of the decline in salmon numbers and tackles the complex role of the Corps. The focus is then narrowed to the lower Snake River and the options available to the Corps as operators of four hydroelectric dams on the river.

One objective for the video is to provide the public, user groups, political staffs, agencies, and the internal Corps audience a factual representation of the study and explain the complexities involved in the recovery of the salmon runs. Another objective is to create enthusiasm and desire to participate in the public involvement program.

The *Path of the Salmon* video has allowed widespread, consistent information dispersal. More than 500 copies of the video in VHS, BETA CAM and CD-ROM formats have been distributed to an extensive variety of groups, schools, and officials. All public and university libraries in communities throughout Washington and Idaho have received a video for their reference sections. A downloadable digital copy of the *Path of the Salmon* was placed on the Feasibility Study Web Site. Portions of the video have been presented in regional as well as national network television broadcasts. The World Commission on Dams based in South Africa requested use of the video for their media production reporting on the status of large dam projects throughout the world. As a tool, the video has provided audiences with factual representation of the study and explained the complexities involved with juvenile salmon migration and multipurpose hydroelectric dams.

4.2 Web Site

A web site page (*http://www.nww.usace.army.mil/lsr*) was established in 1997 to allow internet users access to detailed information about the Feasibility Study (Annex A). One of the pages includes study objectives and details about the alternatives as well as significant schedule milestones. A public outreach page lists upcoming meetings and includes copies of the study newsletter. There are pages on regional coordination, study products, and adult fish counts at the dams. Hot links have been set up providing easy access to web sites that agencies and organizations maintain on related salmon issues.

The web site has proven to be an effective tool for disseminating information to the scientific and educational communities, as well as to stakeholders. The web site was successfully used to distribute times, dates, and locations for a series of 26 regional community assessment forums conducted by the University of Idaho during 1999. The web site has been updated as new information, reports, and links become available.

The media, students, stakeholders, agencies, and community opinion leaders have been able to keep abreast of the study and the scheduled meetings.

4.3 Mailing List

A mailing list was established in order to create a network of individuals interested in the study. From the first scoping meetings in 1995, a mailing list was set up and all subsequent public outreach activities provided opportunities for the public to add their names to the list. The Corps received additional requests for inclusion on the mailing list via letters, e-mail, and telephone calls. Outreach publications like the newspaper insert, newsletter, and Feasibility Study brochures, as well as the Feasibility Study web site, encourage the public to be added to the mailing list.

The mailing list has steadily increased throughout the study to 3,175. The mailing list consists of elected officials, stakeholders, governmental organizations, special interest groups, and interested individuals. The mailing list database has been used to mail out periodic study newsletters and meeting notification cards, as well as for querying specific organizations and contact personnel. Notification of the Draft Feasibility Report/Environmental Impact Statement (FR/EIS) release and the formal public meetings was carried out using the mailing list.

4.4 Newsletter

An informational newsletter format was developed to convey the study progress and upcoming events to the stakeholders and various interested publics. Since June of 1997 when the first newsletter was sent out, several more have followed (see Annex B) that focused on details about the alternatives, Plan for Analyzing and Testing Hypothesis (PATH), Drawdown Regional Economic Workgroup (DREW), Community Assessment Forums, public information meetings, and ongoing regional salmon recovery efforts.

Newsletters have been available at public outreach events and have been sent out in response to information requests. Each issue is posted (in PDF format) on pages available through the internet at the Corps web site. The newsletter has proven to be a valuable tool to keep interested individuals throughout the region informed regarding the study's progress and has also provided an effective means of notification of public meetings on the Feasibility Study.

4.5 Traveling Displays

Two identical portable traveling displays were produced to present basic study information including the timeline and the three alternative pathways and lower Snake River map. This four-panel foldout display (Photo 4-1) creates a mural for a stand-alone exhibit that has been used in a variety of settings: county fairs, outdoor shows, office building foyers, libraries, meetings, and visitor centers. Over one million people have viewed the displays throughout Washington, Idaho, and Oregon (see Annex C).

The objective of the display is to present the Feasibility Study information and process in a manner which creates enthusiasm and a desire to participate in the public involvement program. Cooperation among the varying interest groups is emphasized. The display is designed to answer the following public questions:

- What is the Corps' role in anadromous fish migration on the Snake River System?
- Why should I be interested in this study?
- How can I get involved?

Photo 4-1. Portable Traveling Display

4.6 Brochure

A brochure was produced to present a succinct summary of the Feasibility Study that could be widely distributed at relatively low cost. The two-fold, two-color brochure describes the scope of the Feasibility Study, the Corps role in salmon recovery, and the alternative pathways being analyzed. The importance of regional coordination is emphasized, and the federal agencies working as partners on the study are identified.

The brochure has accompanied the traveling display and all outreach activities so that interested individuals have written material to take with them. The Corps internet address and a telephone point of contact are listed for those who want to follow up on the study or to provide comments.

4.7 Information Sheets

Information and facts about specific elements of the study were summarized into information sheets. These two-page documents were designed as handouts and to be placed on the web site for universal access and easy downloading to provide a succinct overview of topics of interest. Information

sheets on sediment transport, drawdown engineering, recreation/tourism, major system improvements, and community impact assessments were some of the topics included. Information sheets were developed to present the public with a general understanding of detailed study analyses. Information sheets were not intended to be the final answer but rather an introduction to various elements of the study.

4.8 Information Packets

Requests for information about the Feasibility Study have come from a wide variety of sources including students, media, elected officials, stakeholders, and interested citizens. Newsletters, *Salmon Passage Notes*, brochures, newspaper inserts, information sheets, and often copies of *Path of the Salmon* video have been enclosed and sent to interested groups upon request. Media packets have been developed for Media Day and to provide briefing information for visiting officials.

4.9 News Releases and Articles

The Walla Walla District Public Affairs Office has coordinated with local, regional, and national press as well as broadcasting networks on Corps news releases and requests for information on the Feasibility Study. In addition to developing news releases to keep the public informed, coordination with other offices of the Corps and the area elected officials has been a formidable task accomplished by staff in the Public Affairs Office. News releases were also prepared to correct misinformation and specific incorrect information that was called to the reporter's attention by the Public Affairs Office.

News releases have been prepared throughout the study to announce public meetings, community forums, explain alternatives being evaluated, track report progress, and clarify the Corps' mission. Since the start of the Feasibility Study, the Public Affairs Office has provided countless public media requests for details on the wide variety of study elements.

4.10 Radio and Television Broadcasts

The broadcasting networks have, through the coordination of the Public Affairs Office, been deemed essential for disseminating information to the public. The networks have been provided with consistent messages in order to convey accurate and timely information to the general public. Public Affairs Office staff and study team members have worked closely with radio stations and television networks to provide personal interviews, talk show guests, and source information on the Feasibility Study.

4.11 Newspaper Inserts

An 8-page, full-color insert was designed and distributed in October and November 1998 in community and tribal newspapers throughout the lower Snake River region. The insert included study details about the four lower Snake River dams, the alternative pathways being considered, study milestones, public information meeting schedules, and sources for further information on the study.

Distribution of nearly 150,000 copies reached households throughout the region. The inserts produced an immediate reaction in the form of a surge of requests to be added to the mailing list. The study web site page received an increase of several hundred visits after the insert was distributed. The newspaper insert has proven to be an effective, relatively inexpensive method of reaching a large public audience. The newspapers in Table 4-1 included the insert inside their publications. Photo 4-2 is an image from the newspaper insert.

Table 4-1. Newspaper Insert Distribution

Newspaper	City	State
East Washingtonian	Pomeroy	WA
Tri-City Herald	Kennewick	WA
Walla Walla Union Bulletin	Walla Walla	WA
Colfax Gazette	Colfax	WA
Dayton Chronicle	Dayton	WA
Waitsburg Times	Waitsburg	WA
East Oregonian	Pendleton	OR
Hermiston Herald	Hermiston	OR
Lewiston Morning Tribune	Lewiston	ID
Moscow-Pullman Daily News	Moscow	ID
Clearwater Tribune	Orofino	ID
Tribal Newspapers	**City**	**State**
Ta'ts Tito'ogan (Nez Perce)	Lapwai	ID
Confederated Umatilla Journal	Mission	ID
Sho-Ban News (Shoshone Bannok)	Fort Hall	ID
Yakima Nation Review	Toppenish	WA
Spilyay Tymoo (Warm Springs)	Warm Springs	OR

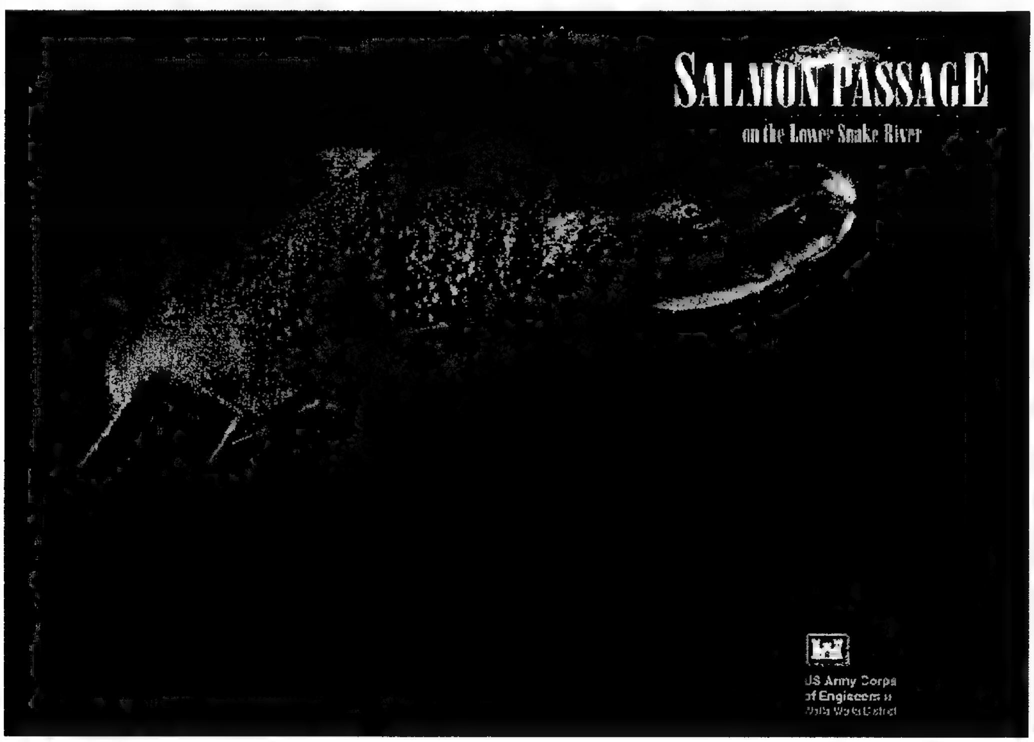


Photo 4-2. Newspaper Insert

4.12 Media Day

Through the annual Media Day in the spring of 1998, 1999, and 2000 the Public Affairs Office provided local and regional media opportunities to focus on the Feasibility Study. The media was afforded the opportunity to meet with Corps technical experts, view prototypes of the surface bypass collector and behavioral guidance structure, and examine the juvenile bypass system and fish transportation barge at Lower Granite Lock and Dam.

The Corps provided a welcoming, site orientation, and Feasibility Study overview presentation at the Lower Granite Dam Visitor Center followed by a question-and-answer session. Media sites (barge and juvenile handling, surface bypass collector-juvenile bypass system, and earth abutment/breaching site) were identified and technical experts were available to explain these features. Media packets for participants were distributed that included a site map with media stations, brochures, newsletters, and fact sheets. Copies of the video *Path of the Salmon* were available upon request. These annual events have been beneficial to keep the media informed about the Feasibility Study so they can, in turn, inform the public. The contacts established during Media Day have proven invaluable throughout many critical phases of the Feasibility Study.

5. Involvement Techniques

The public outreach program involved interested parties in a public dialog at key points in the Feasibility Study. Public involvement consists of two-way communication between the target audience and the Corps. Involvement techniques (i.e., group presentations, discussion opportunities, structured panels, conferences, workshops, community forums, and public information meetings) have allowed interested parties to provide the Corps with feedback on specific study issues and on the Feasibility Study and the alternatives in general (see Annex D, Feasibility Study Outreach Programs 1997 to 1999).

This feedback has been used by the Corps staff in the development of the study. For each public involvement effort, study team staff selected the specific techniques described in the Public Outreach Plan and summarized in the following sections. Formal as well as informal input from the public has provided Corps staff with ongoing and cumulative perspectives that have shaped the overall study.

At each public involvement effort, the Corps identified how feedback would be used. The input was formally reviewed and, where appropriate, has been incorporated into the study. The input has provided the public with an opportunity to influence study scopes and has increased the opportunity for study team members to be exposed to, and to consider, a huge range of public perspectives.

5.1 Public Meetings

A variety of meetings involving the public were carried out as part of the Feasibility Study including initial scoping sessions, roundtable workshops, information meetings, focus group meetings, community assessment forums, and formal public meetings. These gatherings were designed to present specific topics or segments of the Feasibility Study and to encourage public involvement. The meetings have established direct links between the various publics and team members while providing a forum for public comments and input.

5.1.1 Scoping Meetings

The Corps conducted scoping for the Feasibility Study and its associated FR/EIS, through a series of public meetings within the region, in the summer of 1995. Comments received from speakers, letters, and comment cards during the scoping process have been reviewed throughout the Feasibility Study. The comments were classified into 10 general categories as follows:

- consider the range of alternatives
- evaluate the juvenile fish transport program
- incorporate related studies
- consider the loss of river services during dam breaching
- determine what other factors could be affecting salmon runs
- evaluate the cost-benefit of dam breaching
- consider the need for a dam breaching test

- coordinate with other agencies
- consider people's preference for alternative(s)
- offer analysis based on sound science.

5.1.2 Regional Roundtable Workshops

A series of seven roundtable workshops were held around the region with the purpose of encouraging active participation and involvement in the study by public citizens, special interest groups, and communities. Although all workshops were originally planned to be held in Portland, Oregon due to its convenience for many participants, publics from other locations within the region requested workshops in their areas. In addition to Portland, workshops have been conducted in Richland and Clarkston, Washington and in Boise, Idaho. Table 5-1 lists the locations, dates, and number of participants for each regional roundtable workshop. The workshops afforded the opportunity for interested publics to understand and to offer input on specific elements of the study.

Table 5-1. Regional Roundtable Workshops

Town	Date	Meeting Participants
Portland, OR	4/14/97	17
Portland, OR	6/11/97	40
Portland, OR	9/10/97	45
Clarkston, WA	11/12/97	37
Portland, OR	1/21/98	61
Richland, WA	3/18/98	85
Boise, ID	7/15/98	60
TOTAL		**345**

5.1.3 Public Information Meetings

Two series of formal regional public information meetings were conducted in September 1997 and November 1998. The locations, dates, and number of participants from these public information meetings are listed in Table 5-2. The objectives of these meetings were to:

- inform the public and stakeholders about the Feasibility Study status
- hear public concerns
- respond to questions
- stimulate public involvement.

A total of 1,429 people attended the two series of public information meetings. Although formal recording of public comments and questions was not taken during the public information meetings, some study team members took notes on issues that were discussed. Issues raised from the September 1997 meetings were categorized into four broad categories: fish, economics, regional, and study process (Figure 5-1). The issues identified from the November 1998 meetings were

Table 5-2. Public Information Meetings, September 1997, and November 1998

Town	Date	Meeting Participants
September 1997		
Boise, ID	9/17/97	45
Lewiston, ID	9/18/97	100
Kennewick, WA	9/23/97	185
Portland, OR	9/25/97	54
September 1997 subtotal		**384**
November 1998		
Lewiston, ID	11/9/98	300
Richland, WA	11/12/98	300
Portland, OR	11/16/98	140
Boise, ID	11/19/98	85
Spokane, WA	11/23/98	220
November 1998 subtotal		**1,045**
TOTAL		**1,429**

categorized into seven broad categories (Figure 5-2). Analysis of the issue categories and distribution has assisted in providing input to specific study technical evaluations, determining public perceptions, and preparing public outreach efforts.

5.1.4 DREW Focus Meetings

DREW has focused most of its efforts on assembling and analyzing economic and social data through the many work teams. Public interest in the DREW process and input has been welcomed since the work group began in 1997. To better assist the stakeholders and other publics to become involved, several open focus meetings were held in the region. These meetings provided preliminary economic work team evaluations on hydropower, transportation, irrigation, as well as the regional and social analysis (Table 5-3). Valuable input received from the stakeholders and public was used by work teams to clarify analysis parameters.

Table 5-3. DREW Focus Meeting Participation

Town	Date	Meeting Participants
Lewiston, ID	3/3/98	70
Richland, WA	5/27/98	50
Boise, ID	8/26/98	40
TOTAL		**160**

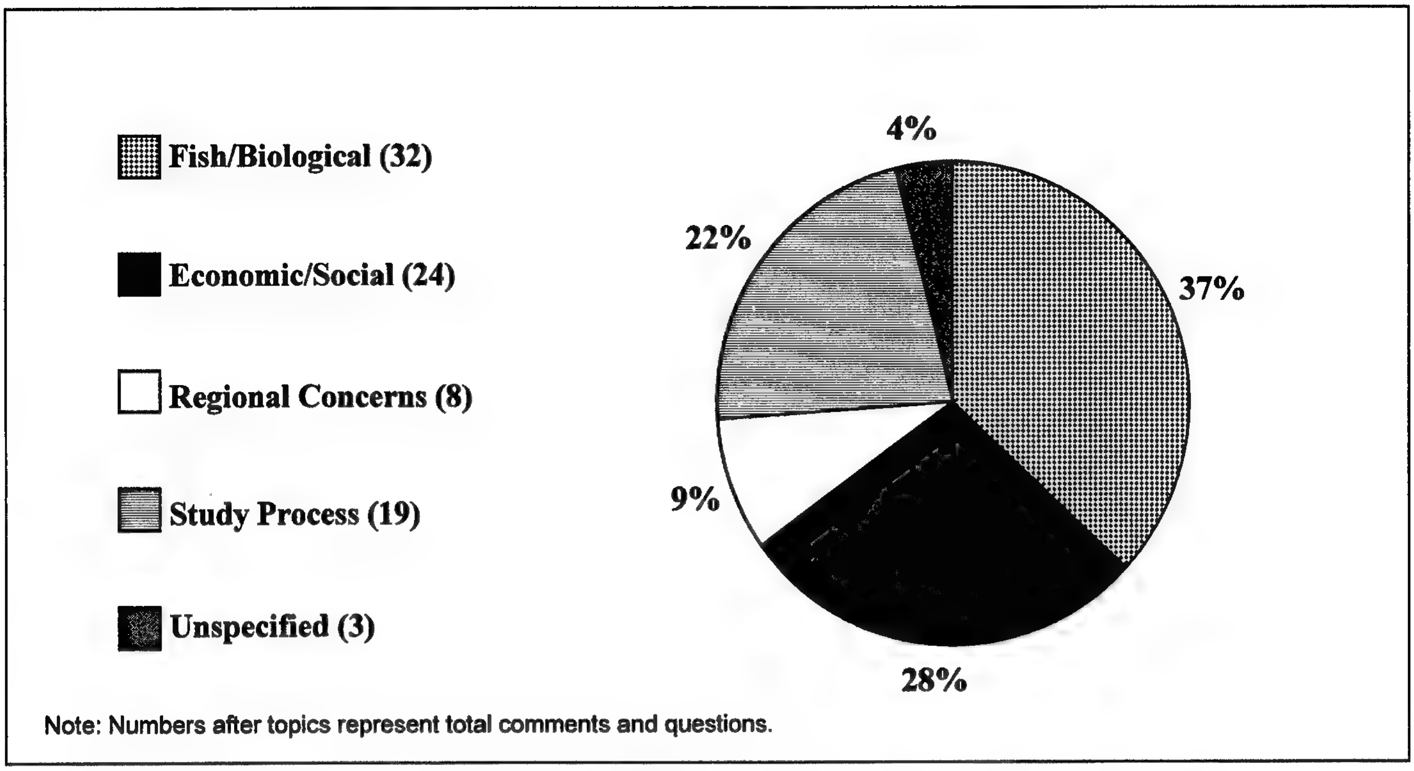


Figure 5-1. Public Information Meetings, September 1997, Categories of Comments and Questions

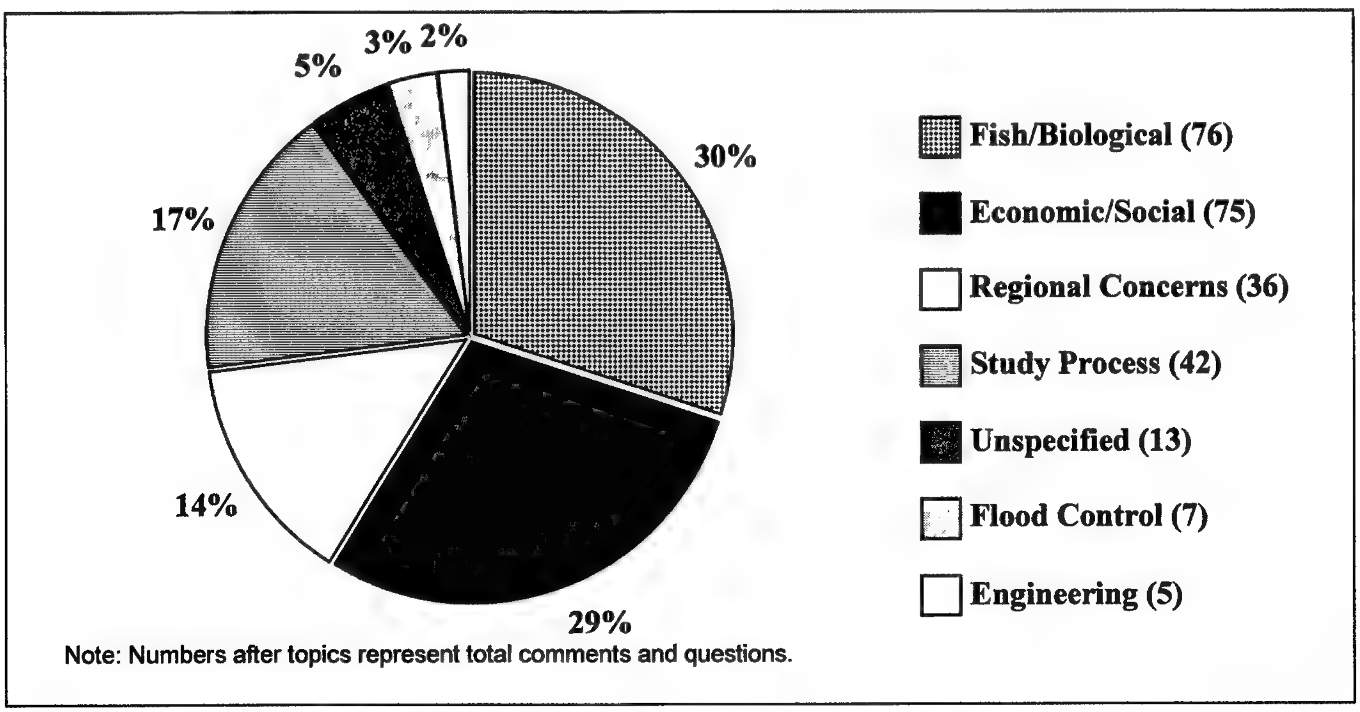


Figure 5-2. Public Information Meetings, November 1998, Categories of Comments and Questions

5.1.5 Community Assessment Forums

More than 1,140 community members throughout the lower Snake River Basin and southern Idaho attended a series of interactive community forums dealing with the Lower Snake River Juvenile Salmon Migration Feasibility Study. These forums were conducted by University of Idaho facilitators for the Corps, and were held in 26 communities throughout the region. The communities were selected to represent the variety of current conditions and potential social impacts in different sized agricultural, timber, recreational, and manufacturing based cities and towns. Table 5-4 lists relevant community forum information.

These community forums were not structured like typical information meetings or public hearings. The University of Idaho provided neutral, interactive forums individually tailored for each community. Community members worked in groups to: explore historic changes that have taken place in communities throughout the basin from 1960 to the present, assess their community's current and future situation, and give their perspective of the likely positive and negative impacts to their community from each of the salmon recovery alternatives currently under investigation by the Corps. A typical community forum is shown in Photo 5-1.

The communities were chosen for their potential to be affected by salmon recovery efforts, their diversity in geographic location, and their differences in social and economic relationships to the Snake River. The first phase of 17 forums was held in late January through March 1999. A second phase of 9 forums was conducted in June 1999 in southern Idaho at the request of local representatives. The southern Idaho community forums addressed the potential effects of flow augmentation measures in addition to the salmon passage alternatives under investigation at the lower Snake River dams.

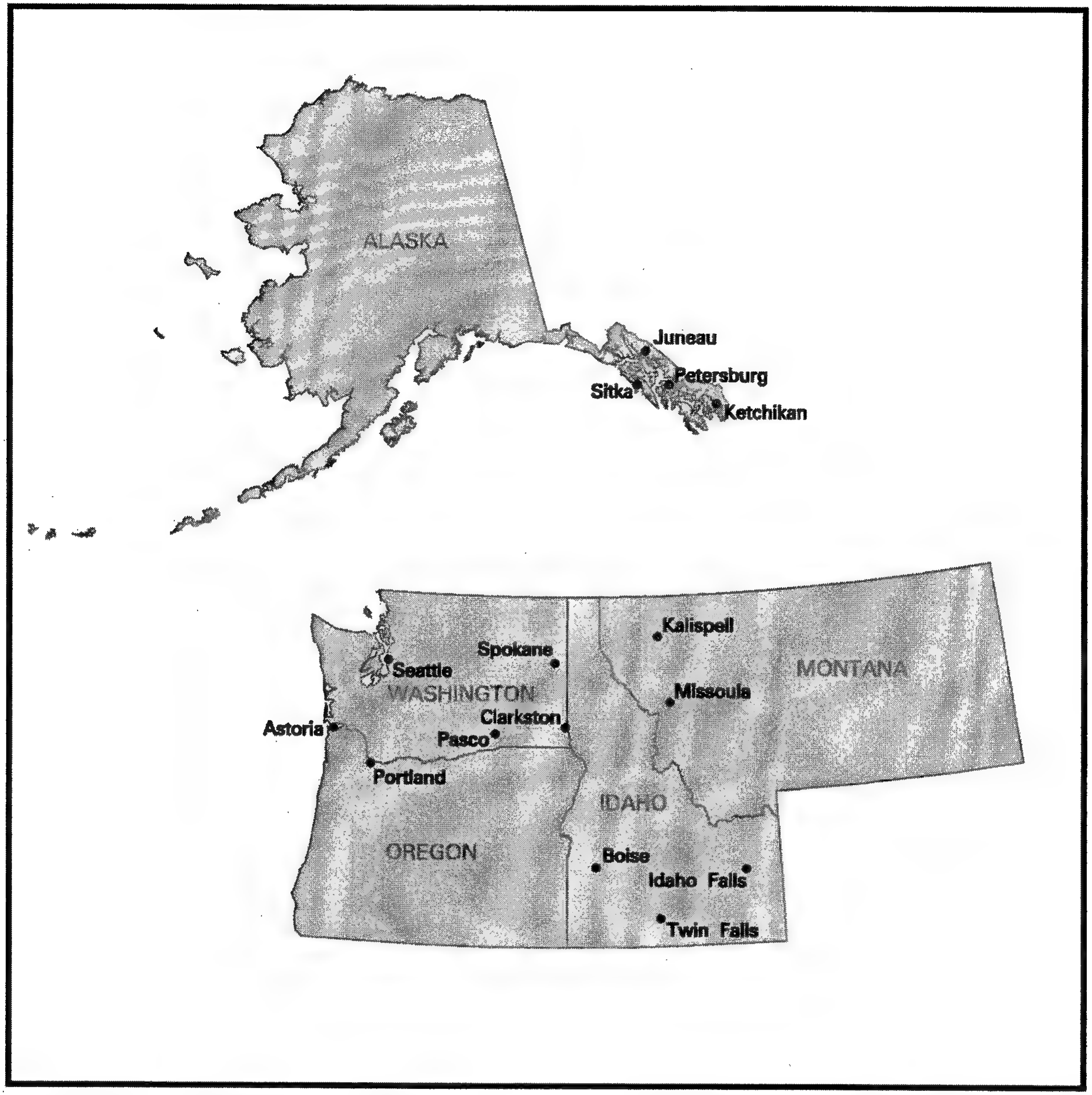
Photo 5-1. Community Forum at Washtucna, Washington

Table 5-4. Community Forum Participation

Town	Date	Number of Community Workshop Participants	Number of Observers	Total Participants
Prescott, WA	1/20/99	51	10	61
Washtucna/Kahlotus, WA	1/26/99	71	124	195
Stanfield, OR	2/8/99	14	9	23
Adams, OR	2/8/99	10	3	13
Umatilla, OR	2/9/99	19	14	33
Burbank, WA	2/11/99	70	22	92
Riggins, ID	2/16/99	26	2	28
Enterprise, OR	2/17/99	23	4	27
Kennewick, WA	2/20/99	19	0	19
Colfax, WA	2/25/99	72	21	93
Pasco, WA	2/27/99	10	13	23
Pomeroy, WA	3/3/99	40	19	59
Weippe, ID	3/4/99	21	5	26
Genesee, ID	3/8/99	37	22	59
Lewiston, ID	3/9/99	33	12	45
Clarkston, WA	3/24/99	36	10	46
Orofino, ID	3/25/99	27	8	35
Salmon, ID	6/14/99	33	0	33
Ashton, ID	6/14/99	13	8	21
Firth, ID	6/15/99	15	21	36
Rupert, ID	6/15/99	21	7	28
Twin Falls, ID	6/16/99	18	18	36
Bliss/Hagerman, ID	6/17/99	21	12	33
Homedale, ID	6/17/99	9	2	11
Boise, ID	6/21/99	49	10	59
Cascade, ID	6/21/99	15	0	15
TOTAL		**773**	**376**	**1,149**

5.1.6 Formal Public Meetings

Formal public meetings were conducted after the Draft FR/EIS was distributed for public review. The series of 15 formal meetings around the region (Figure 5-3) in cooperation with the Federal Caucus, included presentations on the Draft FR/EIS, John Day Drawdown Study, and the Conservation of Columbia Basin Fish All-H Paper. These regional meetings held in February and March 2000 provided an opportunity for formal public questions and comments. A total of nearly 9,000 participants consisting of stakeholders, special interest groups, elected officials, and



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Special Note: States are not displayed at the same scale and projection.

DATE	LOCATION	ATTENDANCE
February 3, 2000	Portland, OR*	1200
February 8, 2000	Spokane, WA*	800
February 10, 2000	Clarkston, WA*	1800
February 15, 2000	Astoria, WA	200
February 17, 2000	Pasco, WA*	1200
February 23, 2000	Boise, ID*	1100
February 29, 2000	Seattle, WA*	550
March 1, 2000	Kalispell, MT	120
March 2, 2000	Missoula, MT	225
March 6, 2000	Ketchikan, AK	72
March 7, 2000	Sitka, AK	130
March 7, 2000	Idaho Falls, ID	520
March 8, 2000	Juneau, AK	151
March 8, 2000	Twin Falls, ID	600
March 9, 2000	Petersburg, AK	91

***2 Sessions**

LOWER SNAKE RIVER
Juvenile Salmon Migration Feasibility Study

Figure 5-3.
FORMAL PUBLIC MEETING LOCATIONS

individuals from the public presented 1,500 oral and taped comments about the two studies and the Federal Caucus paper. Most meetings consisted of an open house, formal agency presentations, a question and answer session, and a public comment session. Oral comments were limited to 3 minutes in length. At some of the meetings, the attendance was so large that not all those wishing to speak were able to do so. In addition to oral and taped comments, the Corps received over 230,000 written comment documents from the public during the comment period. The comment period began December 1999 and extended through April 30, 2000. Written comments were received via mail, e-mail, fax, the Corps' web site, and hand-delivery. For a summary of the oral and written comments received and the responses to these comments, please see Appendix U.

5.2 Briefings for Elected Officials

Interest in the Feasibility Study has ignited the public and received considerable attention from elected officials. The study team members have attempted to keep elected officials and their staffs informed about the study and some of its more controversial aspects. Regional congressional officials and their staffs are sent news releases and are often in contact with the Walla Walla District command element. Several groups of elected officials at different levels of government have toured fish facilities and have been briefed about the Feasibility Study first hand from team members. Congressional staff have regularly attended public meetings and community forums on the Feasibility Study held throughout the region.

5.3 Tours of Facilities

Tours of the Walla Walla District hydropower facilities, especially Lower Granite Dam, have been carried out throughout the life of the Feasibility Study. On-site Corps rangers as well as district office technical staff often conducted these tours. Stakeholders, elected officials, special interest groups, governmental representatives, students, and the media have all toured facilities to better understand juvenile salmon passage issues. Tours are an opportunity to explain and to illustrate project improvements, innovative technology, and problem areas, as well as to discuss the feasibility study alternatives and their potential impacts.

5.4 Speaking Requests

Study team members have been active in responding to public speaking requests (Annex D). Special interest groups, stakeholders, service organizations, universities, professional societies, governmental agencies and others have received presentations about the Feasibility Study from team members. The outreach goal has been to meet all speaking requests so that timely, first-hand, and accurate Feasibility Study information can be presented.

5.5 Personal Communications

The establishment of a central point of contact for coordination of public requests has been consistent. All publications, exhibits, newsletters, and the web site page indicate how to contact the Public Outreach Coordinator. The Project Manager, Lead Planner, Public Affairs Specialist, the Public Outreach Coordinator, and other team members have all assisted with public requests regarding the Feasibility Study. Frequent, open communications between these team members has facilitated consistent, accurate responses to public requests and comments.

The Public Outreach Coordinator has been responsible for addressing telephone calls, e-mail messages, comment cards (meetings), letters, and face-to-face comments and questions. Letter and e-mail responses have been addressed by team members most knowledgeable about the subject of concern or issue. Comments received that required no response were documented as part of our permanent record and thank you cards were sent (Figure 5-4).

Figure 5-4. Thank You Postcard

Thanks for your Letter

We received your comments regarding the Lower Snake River Juvenile Salmon Migration Feasibility Study. We appreciate your views on the study and they will be considered in our evaluations. Your comments are now part of our permanent records. You have been added to our newsletter mailing list and will be informed about study meetings in your area.

For More information:
Dave Dankel
(509)-527-7288
E-Mail: *dave.a.dankel@usace.army.mil*

Thanks again for your interest.

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6. Monitoring Public Outreach Effectiveness

Monitoring public outreach efforts has been accomplished in many ways, ranging from determining web site hits after a news release on meeting schedules to debriefing team members after presentations. No formal surveys were conducted to determine outreach effectiveness.

There has been continued interest throughout the Feasibility Study expressed through e-mail, telephone and written questions, comments, and requests. Information packets, newsletters, and videos have been mailed out to provide interested individuals and organizations with timely, consistent, and accurate information.

Feasibility Study team members have made every reasonable effort to provide an open and effective public outreach effort. Despite busy work schedules, team members also made every effort to meet all requests for speaking engagements or special meetings.

6.1 Video Presentation Feedback

Video Presentation Feedback Forms (see Annex E) were enclosed with each video that was sent out. Feedback on the issues addressed in the video have been received and reviewed. The feedback was used to formulate the Commonly Asked Questions section in the newsletters and to prepare topics for upcoming workshops and public information meetings.

6.2 Community Forum Comment Cards

Over 250 comment cards were received from the public that attended the regional community assessment forums. All cards were read, evaluated, and added to the permanent Feasibility Study official record. In addition, all people who submitted comment cards were added to the master mailing list to receive newsletters and pertinent Feasibility Study information.

6.3 Web Site Analysis

Periodic web site analyses were conducted to determine the effectiveness of this media for communicating information about the Feasibility Study. Data were reviewed that included regional use, most requested pages, most downloaded files, and activity levels (week, day, hour). The web site received over 96,700 hits from mid-December 1999 through the end of April 2000 during the Draft FR/EIS comment period. These analyses have assisted in formulating successful public outreach efforts via the web site.

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7. Glossary

Behavioral guidance structure (BGS)—Long, steel, floating structure designed to simulate the natural shoreline and guide fish toward the surface bypass collection system by taking advantage of their natural tendency to follow the shore.

Dam breaching—In the context of this FR/EIS, dam breaching involves removal of the earthen embankment section at Lower Granite and Little Goose dams, and formation of a channel around Lower Monumental and Ice Harbor dams.

Drawdown— In the context of this FR/EIS, drawdown means returning the lower Snake River to its near-natural flow condition via dam breaching.

Juvenile fish transportation system—System of barges and trucks used to transport juvenile salmon and steelhead from the lower Snake River or McNary Dam to below Bonneville Dam for release back to the river; alternative to in-river migration.

Plan for analyzing and testing hypotheses (PATH)—A workgroup comprised of regional fishery biologists using qualitative and quantitative analysis to measure the effects on listed salmon stocks under numerous river and salmon management alternatives.

Public information—One-way information communicated to an audience, with little or no opportunity for feedback.

Public involvement—Two-way communication between the Corps and the target participants, aimed at providing the Corps with feedback on the Feasibility Study, study issues, and the alternatives.

Stakeholder—An individual or group that has a vested interest in the outcome of a study or project.

Surface bypass collector (SBC) system—A system designed to divert fish at the surface before they have to dive and encounter the existing turbine intake screens. SBC systems direct the juvenile fish into the forebay, where they are passed downstream either through the dam spillway or via the juvenile fish transportation system of barges and trucks.

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Annex A

Feasibility Study Web Page

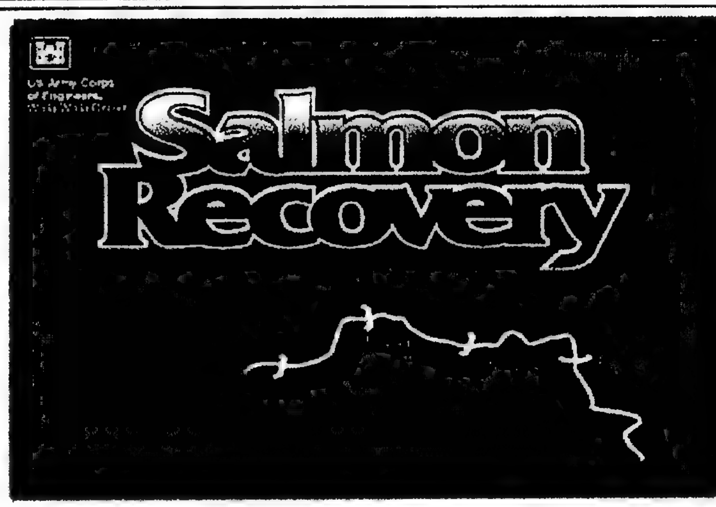
US Army Corps
of Engineers®
Walla Walla District

Lower Snake River Juvenile Salmon Migration Feasibility Study Index

Public Information

Draft Feasibility Report and Environmental Impact Statement (FR/EIS)
NOTE to Internet Explorer 4.5 & 5.0 Users

- Information Sheets
- The Study
- Significant Milestones
- Public Outreach
- Products
- Adult Fish Counts
- Regional Coordination
- Links to Other Items of Interest



Columbia Basin Salmon Recovery Strategy
Final 2000 FCRPS Biological Opinion

Return to the Walla Walla District Home Page

Find your information quickly on the Site Map.

Study Comments/Order Information

Privacy and Security Notice

The POC for this page:

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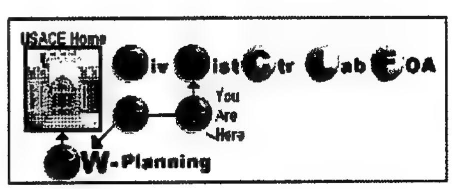

Annex B

Feasibility Study Newsletter Issues

Annex B

Feasibility Study Newsletter Issues

<u>Newsletter No.1 - June 1997</u>

- Feasibility Study Background
- Regional Coordination
- Feasibility Study Scope and Objectives
- Key Terms
- Regional Roundtable Meeting
- Feasibility Study Areas of Consideration
- Schedule

<u>Newsletter No. 2 – September 1997</u>

- Feasibility Study Update
- Public Information Meeting Schedule
- Regional Coordination Update
- Feasibility Study Goals and Pathways
- Existing System Pathway
- Juvenile Salmon Migration
- Study Milestones

<u>Newsletter No. 3 – June 1998</u>

- Study Update
- Roundtable Workshop Schedule
- Regional Coordination Update
- Major System Improvement Pathway (Part I)
- Focus Issue PATH
- Study Milestones
- Commonly Asked Questions
- Study Team list

<u>Newsletter No. 4 – October 1998</u>

- Study Update
- Public Meeting Schedule
- Regional Coordination Update
- Major System Improvement Pathway (Part II)
- Focus Issue DREW
- Study Milestones
- Commonly Asked Questions

Newsletter No. 5 – January 1999

- Study Update
- NMFS Public Makeup Meeting
- Regional Coordination
- Natural River Drawdown Pathway (Part I)
- Commonly Asked Questions
- Study Milestones

Newsletter No. 6 – April 1999

- Study Update
- NMFS Anadromous Fish Appendix
- Commonly Asked Questions
- Regional Coordination Update
- Natural River Drawdown Pathway (Part II)
- NMFS Additional Salmon ESA Listings
- Study Milestones

Newsletter No. 7 – August 1999

- Study Update
- Columbia-Snake River Studies (Fed. Caucus & Multi-species Fr.)
- Commonly Asked Questions
- Community Assessment Forums – S. Idaho
- Study Milestones

Newsletter No. 8 – January 2000

- Study Update
- Regional Coordination
- Formal Public Meeting Schedule (Corps & Federal Caucus)
- Draft FR/EIS Alternatives (includes actions & effects)
- Study Milestones

Newsletter No. 9 – July 2000

- Study Update
- Study on Public Meetings
- Sediment Transport Analysis – Information Sheet
- Spring Chinook Runs
- Study Milestones

Newsletter No. 10 – August 2001

- Study Update
- Comment Analysis Process Completion
- Commonly Asked Questions
- Federal Agency Document Releases
- Removable Spillway Weir
- Study Milestones

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Annex C

Display Schedules 1997-2001

Annex C

SALMON FEASIBILITY STUDY DISPLAY 1997 SCHEDULE

DATE	LOCATION	COORDINATOR	VIEWERS
26 Aug-2 Sep	Walla Walla County Fair Walla Walla, WA	Dave Dankel	1500
13-14 Sep	Technology Fair Nat. Guard Armory, Walla Walla, WA	Dennis Jones	1000
16 Sep	Walla Walla District COE Walla Walla, WA	Dave Dankel	50
17 Sep	Study Public Meeting Boise State U, ID	Dave Dankel	45
18 Sep	Study Public Meeting Lewiston, ID	Dave Dankel	100
15-22 Sep	Nez Perce County Fair COE Clarkston, WA	Craig Rockwell	5000
23 Sep	Study Public Meeting Kennewick, WA	Dave Dankel	185
24 Sep-29 Oct	Dworshak Visitor Center Dworshak Dam, ID	Joyce Dunning	1100
25 Sep	Study Public Meeting Portland, OR	Dave Dankel	54

SALMON FEASIBILITY STUDY DISPLAY
1997 SCHEDULE, CONTINUED

DATE	LOCATION	COORDINATOR	VIEWERS
3-14 Oct	Richland City Hall Richland, WA (Public Power Week)	Linda Ehrlick or Gail Braasch	500
28-30 Oct	Walla Walla AFEP Annual Review, Whitman College Walla Walla, WA	Rebecca Kalamasz	200
29 Oct-31 Dec	Pacific Salmon Visitor Information Center-McNary Dam, Umatilla, OR	Pasquale Anolfo	4,670

SALMON FEASIBILITY STUDY DISPLAY 1998 SCHEDULE

DATE	LOCATION	COORDINATOR	VIEWERS
1 Jan - 10 Mar	Pacific Salmon Visitor Information Center - McNary Dam, Umatilla, OR	Pasquale Anolfo	6,240
17 Dec-7 Aug	Hiram M. Chittenden Locks Visitor Center-Seattle, WA *Path of Salmon* viewed (690 times)	Craig Lykins	92,425
19-22 Mar	Big Horn Sports & Rec Show Fair Grounds – Spokane, WA	Jaymi Osborn	2,600
18 Apr	Earth Day Celebration Richland, WA	Gail Baach	750
1Jun-1 Oct	Bonneville Dam Visitor Center Cascade Locks, OR *Path of Salmon* viewed (488 times)	Pat Barry	281,368
19-22 Jul	Ports, Waterways, & International Trade Conference Seattle, WA	Dave Dankel	210
8-30 Aug	Walla Walla District COE Walla Walla, WA	Dave Dankel	200
26 Aug- 19 Nov	Boise Center on the Grove Convention Center - Boise, ID	Dave Dankel	71,390
5-13 Oct	Public Power Week Richland, WA	Dave Dankel	450

SALMON FEASIBILITY STUDY DISPLAY 1998 SCHEDULE, CONTINUED

DATE	LOCATION	COORDINATOR	VIEWERS
16 Nov-	Northwest Division COE Portland, OR	Clare Perry	(See 1999)
20 Nov-	Boise State U. Library Boise, ID	Janet Strong	(See 1999)

SALMON FEASIBILITY STUDY DISPLAY 1999 SCHEDULE

DATE	LOCATION	COORDINATOR	VIEWERS
16 Nov98- 1 Feb	Northwest Division COE Portland, OR	Clare Perry	525
20 Nov98-2Mar	Boise State U. Library Boise, ID	Janet Strong	3,500
18-21 Mar	Big Horn Sports & Rec Show Fair Grounds – Spokane, WA	Charles Craddock Jaymi Osborn	5,000
1-16 April	Walla Walla District Bldg. Walla Walla, WA	Dave Dankel	700
17April99	Earth Day Celebration Richland, WA	Gail Baasch	5,000
19-27 April	Walla Walla Public Library Walla Walla, WA	Martha Van Pelt	3,114
28April-6May	Edwin Markham School Pasco, WA	Linda Hammer	350
5-May-31Oct99	Bonneville Dam Visitor Center Cascade Locks, OR	Pat Barry	405,111
16-22 May99	Society of Wetland Scientists PNW Meeting, Newport, OR	Lonnie Mettler	300
28May-8Oct99	Lower Granite Dam Visitor Center, WA	Cari Caruso	19,000

SALMON FEASIBILITY STUDY DISPLAY 1999 SCHEDULE, CONTINUED

DATE	LOCATION	COORDINATOR	VIEWERS
9Oct-17Nov99	Seattle Public Library Downtown Seattle, WA	John Sheets	123,295
18-20Nov 99	Fish Expo Seattle, WA	Tom Archambault	10,500
21Nov-	Seattle Public Library Downtown Seattle, WA	John Sheets	(see 2000)

SALMON FEASIBILITY STUDY DISPLAY 2000 SCHEDULE

DATE	LOCATION	COORDINATOR	VIEWERS
21Nov-31Jan	Seattle Public Library Downtown Seattle, WA	John Sheets	220,833
3Feb00	Public Meeting DEIS/Caucus Portland, OR	Dave Dankel	1,200
8Feb00	Public Meeting DEIS/Caucus Spokane, WA	Dave Dankel	800
10Feb00	Public Meeting DEIS/Caucus Clarkston, WA	Lonnie Mettler	1,800
13Feb- 1Dec00	Lower Granite Dam Visitor Center, WA	Dawn Wiedmeier	36,972
15Feb00	Public Meeting DEIS/Caucus Astoria, OR	Dave Dankel	100
17Feb00	Public Meeting DEIS/Caucus Pasco, WA	Dave Dankel	1,200
23Feb00	Public Meeting DEIS/Caucus Boise, ID	Dave Dankel	1,100
29Feb00	Public Meeting DEIS/Caucus Seattle, WA	Dave Dankel	550
7Mar00	Public Meeting DEIS/Caucus Idaho Falls, ID	Dave Dankel	520

DATE	LOCATION	COORDINATOR	VIEWERS
8Mar00	Public Meeting DEIS/Caucus Twin Falls, ID	Dave Dankel	600
20Apr-30Nov00	Pacific Salmon Visitor Information Center McNary Dam, OR	Pasquale Anolfo	46,132
22Apr00	Earth Day Celebration Walla Walla, WA	Dave Dankel	150
10May-1Nov00	Visitor Center Ice Harbor Dam, WA	Dan Dunnet	33,500

SALMON FEASIBILITY STUDY DISPLAY 2001 SCHEDULE

DATE	LOCATION	COORDINATOR	VIEWERS
1Jan- 31Dec	Lower Granite Dam Visitor Center, WA	Dawn Wiedmeier	47,092
1Jan-31Dec	Pacific Salmon Visitor Information Center McNary Dam, OR	Pasquale Anolfo	59,673
Jan-9Apr	Visitor Center Ice Harbor Dam, WA	Jeanne Newton	3,202
12Apr-31Dec	Bonneville Dam Visitor Center Cascade Locks, OR	Pat Barry	249,553
16-20Apr	USACE Environmental Development Workshop Portland, OR	Dave Dankel	575
21May-31Dec	Visitor Center Ice Harbor Dam, WA	Jeanne Newton	53,250

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Annex D

Feasibility Study Outreach 1997-2001

Annex D

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY 1997 OUTREACH

DATE	GROUP/LOCATION	PRESENTER	AUDIENCE
14APR97	Regional Roundtable Workshop - Portland, OR	Greg Graham	17
11JUN97	Regional Roundtable Workshop - Portland, OR	Greg Graham	40
3JUL97	Senator Craig Tour Lower Granite Dam, WA	Greg Graham	15
31JUL97	Tribal Consultation Mtg Walla Walla, WA	Greg Graham	10
10SEP97	Regional Roundtable Workshop - Portland, OR	Greg Graham	45
16SEP97	Lunch bag Awareness COE - Walla Walla, WA	Greg Graham	20
16SEP97	LSR Recreation Lessees COE - Walla Walla, WA	Pete Poolman	20
17SEP97	Public Information Meeting Boise State U. – Boise, ID	Greg Graham	45
18SEP97	Public Information Meeting Lewiston, ID	Greg Graham	100
23SEP97	Public Information Meeting Kennewick, WA	Greg Graham	185

1997 OUTREACH, CONTINUED

DATE	GROUP/LOCATION	PRESENTER	AUDIENCE
25SEP97	Public Information Meeting Portland, OR	Greg Graham	54
6OCT97	CRITFIC Portland, OR	Greg Graham	5
9OCT97	International Exchange Conference, Lewiston, ID	Greg Graham	35
21OCT97	Walla Walla Kiwanis Walla Walla, WA	Greg Graham	25
30OCT97	Department of Justice Portland, OR	Greg Graham	50
12NOV97	Regional Roundtable Workshop - Clarkston, WA	Greg Graham	37
18NOV97	DREW-Public Focus Mtg Richland, WA	Dennis Wagner	45
16DEC97	American Assoc Cost Eng Richland, WA	Lonnie Mettler	25

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY 1998 OUTREACH

DATE	GROUP/LOCATION	PRESENTER	AUDIENCE
21JAN98	Roundtable Workshop Portland, OR	Greg Graham	61
29JAN98	Williams College (On Tour) McNary Dam VIC, OR	Lonnie Mettler	14
4FEB98	Walla Walla College Environ. Stewardship Class Walla Walla, WA	Dave Dankel	15
5FEB98	Asotin County Conservation District, Asotin, WA	Greg Graham	50
10FEB98	Harvest States Mgrs Assoc Portland, OR	Greg Graham	200
18FEB98	Kiwanis Club Dayton, WA	Dave Dankel	11
3MAR98	DREW-Public Focus Mtg Lewiston, ID	Dennis Wagner	70
16MAR98	WW High School FFA Walla Walla, WA	Poolman, Dankel Tatro, Mettler, Pinney	6
18MAR98	Roundtable Workshop Richland, WA	Greg Graham	85
25MAR98	WA State U class Richland, WA	Lonnie Mettler	30

1998 OUTREACH, CONTINUED

DATE	GROUP/LOCATION	PRESENTER	AUDIENCE
26MAR98	Potlatch Corporation Walla Walla, WA	Pete Poolman Gary Ellis	13
11APR98	BPA-Future Fish Funding Portland, OR	Greg Graham	40
13APR98	BPA-Future Fish Funding Boise, ID	Greg Graham	20
18APR98	Earth Day- Howard Amon Park - Richland, WA	Dave Dankel	750
20APR98	BPA-Liaison Group Tour LGR Dam, WA	Mike Mason	15
22APR98	KGDC Radio interview Walla Walla, WA	Lonnie Mettler	7,000
22APR98	Contracting Division COE - Walla Walla, WA	Dave Dankel	16
23APR98	Natural History Speakers McNary Dam, OR	Dave Dankel	23
24APR98	Partnering for Success Small Bus Fair Spokane, WA	Sandy Thomas	250
28APR98	Regional Media Day LGR Dam, WA	Dutch Meier	9
29APR98	Dworshak Project Staff Ahsahka, ID	Dave Dankel	12

1998 OUTREACH, CONTINUED

DATE	GROUP/LOCATION	PRESENTER	AUDIENCE
7MAY98	ID Fish & Game Dept & Commission Tour LGR Dam, WA	Mike Mason	30
14MAY98	Bonneville Power Admin. Independent Investors Tour LGR Dam, WA	Mike Mason	30
15MAY98	Council of Environ Quality & NMFS Tour LGR Dam, WA	Mike Mason	6
26MAY98	Tri-cities Econ. Committee Richland, WA	Pete Poolman Gary Ellis	20
27MAY98	DREW-Public Focus Mtg Richland, WA	Dennis Wagner	50
2JUN98	WW County Commissioners & Ag Representatives Walla Walla, WA	Garry Ellis Dave Dankel Pete Poolman	16
3JUN98	Walla Walla College Engineering Class Walla Walla, WA	Steve Tatro	25
4JUN98	Bureau of Reclamation Worshop 1.427 MAF Boise, ID	Lonnie Mettler Pete Poolman	27
8JUN98	American Society Civil Eng National Conference Chicago, IL	Greg Graham	30
4-26 JUN98	Irrigator Briefings Snake River sites, WA	Steve Tatro	15

1998 OUTREACH, CONTINUED

DATE	GROUP/LOCATION	PRESENTER	AUDIENCE
15JUL98	Idaho Department of Fish & Game, Boise, ID	Greg Graham	3
15JUL98	Roundtable Workshop Boise, ID	Greg Graham	60
16JUL98	Shoshone-Bannock Tribe Briefing - Fort Hall, ID	Gerg Graham	25
22JUL98	Ports, Waterways, & Interntl Trade Conference Seattle, WA	Jim Fredricks	125
29-31 JUL98	International Hydrovision Conference, Reno, NV	Charlie Krahenbuhl	250
26 AUG98	DREW Public Focus Meeting - Boise, ID	Dennis Wagner	40
5 OCT 98	EPA (Region Exec & Staff) Portland, OR	Greg Graham	125
6 OCT 98	WA Agriculture & Forestry Ed Foundation Vancouver, WA	Greg Graham	25
13 OCT98	Assoc. of Dam Officials Las Vegas, NV	Steve Tatro	600
14 OCT98	Leadership Walla Walla Walla Walla, WA	Greg Graham	20
22 OCT98	Salmon Conference Spokane, WA	Greg Graham	120

1998 OUTREACH, CONTINUED

DATE	GROUP/LOCATION	PRESENTER	AUDIENCE
29 OCT98	NW Timber Workers Lewiston, ID	Lonnie Mettler	17
29 OCT98	COE Eastern Project Staff, Clarkston, WA	Dave Dankel	13
4 NOV98	American Public Works Assoc. - Wenatchee, WA	Dave Dankel	50
9 NOV98	Public Information Meeting Lewiston, ID	Greg Graham	300
12NOV98	Public Information Meeting Richland, WA	Greg Graham	300
13NOV98	Pioneer Jr. HS Walla Walla, WA	Tim Wik	75
16NOV 98	Public Information Meeting Portland, OR	Greg Graham	140
19NOV98	Public Information Meeting Boise, ID	Greg Graham	85
23NOV98	Public Information Meeting Spokane, WA	Greg Graham	220
30NOV98	Evergreen Retirement Milton-Freewater, OR	Dave Dankel	7
3DEC98	Columbia Center Rotary Kennewick, WA	Lonnie Mettler	100
16DEC98	Columbia County Grain Growers – Dayton, WA	Dave Dankel	60

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY 1999 OUTREACH

DATE	GROUP/LOCATION	PRESENTER	AUDIENCE
6JAN 99	Masons Walla Walla, WA	Greg Graham	20
6JAN99	Columbia Basin WA Native Plant Society-Kennewick, WA	Scott Ackerman	28
20JAN99	Palouse-Rock Lake Conservation District Mtg St. John, WA	Dave Dankel	70
20JAN99	Community Forum Prescott, WA	U. of Idaho	61
26JAN99	U of Idaho, Public Involvement Class Moscow, ID	Dave Dankel	25
26JAN99	Community Forum Washtucna, WA	U. of Idaho	195
27JAN99	NMFS Public Meeting Pasco, WA	Tom Cooney	250
3FEB99	Pasco/Kennewick Rotary Kennewick, WA	Greg Graham	100
4FEB99	Milton-Freewater Gunclub Milton-Freewater, OR	Greg Graham	22

1999 OUTREACH, CONTINUED

DATE	GROUP/LOCATION	PRESENTER	AUDIENCE
6FEB99	Sierra Club Public Ed Workshop – Seattle, WA	Greg Graham	90
8FEB99	Community Forum Adams, OR	U. of Idaho	13
8FEB99	Community Forum Stanfield, OR	U. of Idaho	23
9FEB99	Palouse Conservation District- Pullman, WA	Greg Graham	60
9FEB99	Community Forum Umatilla, OR	U. of Idaho	33
11FEB99	Community Forum Burbank, WA	U. of Idaho	92
16FEB99	Community Forum Riggins, ID	U. of Idaho	28
17FEB99	Community Forum Enterprise, OR	U of Idaho	27
17FEB99	KOHU Radio Program Hermiston, OR	Greg Graham	5,000
18FEB99	Stevens County Fed Land Advisory Board, Colville, WA	Greg Graham	25
20FEB99	Community Forum Kennewick, WA	U. of Idaho	19
22FEB99	Tribal Consultation Richland, WA	Mike Mason	11

1999 OUTREACH, CONTINUED

DATE	GROUP/LOCATION	PRESENTER	AUDIENCE
22FEB99	Buena Grange Buena, WA	Greg Graham	50
24FEB99	Evergreen Rehab Center Milton-Freewater, WA	Anneli Aston	8
24FEB99	Prescott Home Ec Club Elks-Walla Walla, WA	Dave Dankel	22
25FEB99	World Commission on Dams, Lower Granite Dam	Brayton Willis	3
25FEB99	Community Forum Colfax, WA	U. of Idaho	93
27FEB99	Community Forum Pasco, WA	U. of Idaho	23
3MAR99	Community Forum Pomeroy, WA	U. of Idaho	59
3MAR99	Chamber of Commerce Dayton, WA	Dave Dankel	18
4MAR99	Community Forum Weippe, ID	U. of Idaho	26
8MAR99	Community Forum Genesee, ID	U. of Idaho	59
9MAR99	Community Forum Lewiston, ID	U. of Idaho	45
10MAR99	American Society of Engineers – Richland, WA	Steve Tatro	35

1999 OUTREACH, CONTINUED

DATE	GROUP/LOCATION	PRESENTER	AUDIENCE
11MAR99	Walla Walla Valley Medical Society - Walla Walla, WA	Lonnie Mettler	48
24MAR99	Community Forum Clarkston, WA	U. of Idaho	46
25MAR99	Community Forum Orofino, ID	U. of Idaho	35
28MAR99	WA Assoc of PUD's Ice Harbor Dam, WA	Greg Graham	30
2APR99	Clearwater Power Co Tour LGR Dam, WA	Greg Graham	15
3APR99	Environmental Law Society U of Idaho School of Law Moscow, ID	Janet Smith	25
9APR99	Grain Elevator & Processing Society Kennewick, WA	Greg Graham	25
12APR99	NW Grain & Feed Assoc Pasco, WA	Lonnie Mettler	50
13APR99	ID Customer Utility Assoc Tour LGR Dam, WA	MikeMason John McKern	13
20APR99	Milton Freewater Rotary Milton Freewater, OR	Lonnie Mettler	50
22APR99	Media Day-99 LGR Dam, WA	Dutch Meier	10

1999 OUTREACH, CONTINUED

DATE	GROUP/LOCATION	PRESENTER	AUDIENCE
22APR99	Earth Day Symposium WSU-Richland, WA	Lonnie Mettler	30
5MAY99	Col, Basin Fish & Wildlife Authority (CBFWA) Coeur d'Alene, ID	Greg Graham	75
5MAY99	ID Farm Growers Tour LGR Dam, WA	Mike Mason	20
5MAY99	WWCC-Quest Class Walla Walla, WA	Dave Dankel	12
6MAY99	Kiwanis Club Milton-Freewater	Dave Dankel	15
6MAY99	Edwin Markham School Pasco, WA	Anneli Aston	65
12MAY99	Pacific Seed Assoc. Annual Conference Lincoln City, OR	Greg Graham	50
17MAY99	Ecosystem Mgmt Class WSU - Pullman, WA	Dave Dankel	30
19MAY99	WA State Envirothon Tour LGR Dam, WA	Dave Dankel	120
20MAY99	Northwest Power Planning Council, Tour LGR Dam	Mike Mason	2
21MAY99	Lower Valley Light & Power Cooperative Tour LGR Dam, WA	Greg Graham	15

1999 OUTREACH, CONTINUED

DATE	GROUP/LOCATION	PRESENTER	AUDIENCE
25MAY99	Briefing Idaho Reps & Gov Community Forums Boise, ID	Greg Graham	20
7JUN99	Association of Professional Engineers - Spokane, WA	Greg Graham	40
11JUN99	WA Public Utilities Districts Association with WA Legislators Stevenson, WA	Greg Graham	80
14JUN99	Community Forum Salmon, ID	U. of Idaho	33
14JUN99	Community Forum Ashton, ID	U. of Idaho	21
15JUN99	Community Forum Firth, ID	U. of Idaho	36
15JUN99	Community Forum Rupert, ID	U. of Idaho	28
16JUN99	Community Forum Twin Falls, ID	U. of Idaho	36
17JUN99	Community Forum Hagerman/Bliss, ID	U. of Idaho	33
17JUN99	Community Forum Homedale, ID	U. of Idaho	11
17JUN99	Ann Shields Chief of Staff Sec of Interior, Tour LGR Dam	Mike Mason	4

1999 OUTREACH, CONTINUED

DATE	GROUP/LOCATION	PRESENTER	AUDIENCE
18JUN99	WA League of Women Voters Annual Convention Spokane, WA	Greg Graham	150
21JUN99	Community Forum Boise, ID	U. of Idaho	59
22JUN99	Community Forum Cascade, ID	U. of Idaho	15
22JUN99	WA Association of Wheat Growers with WA Legislators	Greg Graham	75
28JUN99	Greater Pasco Chamber of Commerce – Pasco, WA	Greg Graham	50
30JUN99	Palouse Conservation Distr. Annual Tour Wawawai Park, WA	Dawn Wiedmeier	30
14JUL99	Idaho Youth Group Tour LGR Dam, WA	John McKern & Dave Dankel	80
21JUL99	Columbia River Treaty Operating Committee Tour LGR Dam, WA	Greg Graham	25
18AUG99	LCSC Elderhostel Lewiston, ID	John McKern	40
28AUG99	Society of American Military Engineers Walla Walla, WA	Greg Graham	15

1999 OUTREACH, CONTINUED

DATE	GROUP/LOCATION	PRESENTER	AUDIENCE
4AUG99	Society of American Military Engineers Portland, OR	Steve Tatro	30
4AUG99	COE Geotechnical Conference, Portland, OR	Steve Tatro	75
18AUG99	Elderhostel – Lewis & Clark State College Lewiston, ID	John McKern	40
22SEP99	Natural Resources Comm WA State Senate Tour McNary Dam, OR	Mike Mason	6
7OCT99	WA Agriculture & Forestry Education Foundation Vancouver, WA	Greg Graham	30
13OCT99	Leadership Walla Walla Foundation Walla Walla, WA	Greg Graham	20

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY

2000 OUTREACH

DATE	GROUP/LOCATION	PRESENTER	AUDIENCE
11JAN00	Pacific NW Farm Forum Spokane, WA	Greg Graham	25
18JAN 00	Rotary International Milton-Freewater, OR	Greg Graham	40
20JAN00	Symposium on Dams, Reservior, & Nature Wetlands International Tokyo, Japan	John McKern	200
20JAN00	Columbia/Snake River Irrigators Kennewick, WA	Greg Graham	25
27JAN00	Columbia REA Vista Hermosa, WA	Dave Dankel	25
29JAN00	KGDC-AM Radio Show Walla Walla, WA	Greg Graham	1,000
1FEB00	Walleye Club Walla Walla, WA	Greg Graham	40
3FEB00	Public Meeting DEIS/Caucus Portland, OR	Study Team	1,200
8FEB00	Public Meeting DEIS/Caucus Spokane, WA	Study Team	800

DATE	GROUP/LOCATION	PRESENTER	AUDIENCE
10FEB00	Public Meeting DEIS/Caucus Clarkston, WA	Study Team	1,800
10FEB00	Water Coalition Hermiston, OR	John McKern	50
15FEB00	Public Meeting DEIS/Caucus Astoria, OR	Study Team	200
15FEB00	Whitman College Class Walla Walla, WA	John McKern	15
15FEB00	Environmental Stewardship Class, Walla Walla Colllege Walla Walla, WA	Lonnie Mettler	13
17FEB00	Public Meeting DEIS/Caucus Pasco, WA	Study Team	1,200
23FEB00	Public Meeting DEIS/Caucus Boise, ID	Study Team	1,100
29FEB00	Public Meeting DEIS/Caucus Seattle, WA	Study Team	550
1MAR00	Public Meeting DEIS/Caucus Kalispell, MT	Study Team	120

DATE	GROUP/LOCATION	PRESENTER	AUDIENCE
2MAR00	Public Meeting DEIS/Caucus Missoula, MT	Study Team	225
6MAR00	Public Meeting DEIS/Caucus Ketchikan, AK	Study Team	72
7MAR00	Public Meeting DEIS/Caucus Idaho Falls, ID	Study Team	520
7MAR00	Public Meeting DEIS/Caucus Sitka, AK	Study Team	130
8MAR00	Public Meeting DEIS/Caucus Twin Falls, ID	Study Team	600
8MAR00	Public Meeting DEIS/Caucus Juneau, AK	Study Team	151
9MAR00	Public Meeting DEIS/Caucus Petersburg, AK	Study Team	91
31MAR00	National Assoc. of Business Economists Portland, OR	Greg Graham	30
3APR00	Exchange Club Walla Walla, WA	Greg Graham	100

DATE	GROUP/LOCATION	PRESENTER	AUDIENCE
8APR00	U. of Idaho-Borah Seminar NW Nat. Resource Issues Snake River Tour	Greg Graham	35
11APR00	Whitman College – Senior Seminar-Gov. & Environ. Walla Walla, WA	Greg Graham	15
16APR00	WA State PUD Assoc. Seattle, WA	Greg Graham	30
17APR00	Pacific NW Grain & Feed Assoc. – Pendleton, OR	Greg Graham	80
19APR00	Tour Congressional Tour LGR Dam, WA	Greg Graham	8
20APR00	Acting Asst. Sec Commerce Tour LGR Dam, WA	Mike Mason	3
21APR00	Asst Sec. of Energy Tour LGR Dam, WA	Mike Mason	7
22APR00	Earth Day Celebration Walla Walla, WA	Dave Dankel	150
26APR00	Media Day Tour LGR Dam, WA	Dutch Meier	8
4MAY00	American Waterworks Annual Conference Spokane, WA	Greg Graham	110
11MAY00	School of Environment Duke University Tour LGR Dam, WA	Mike Mason	23

DATE	GROUP/LOCATION	PRESENTER	AUDIENCE
16MAY00	Sacajawea Jr High Class Lewiston, ID	Dave Dankel	100
31MAY00	Edison Elementary Walla Walla, WA	Chris Pinney/ Dave Dankel	30
31MAY00	Eileen McLellan-OR Senator Wyden's Office Tour LGR Dam, WA	Mike Mason	1
2JUN00	Ranger staff briefing LGR Dam, WA	Dave Dankel	5
19JUN00	International Symposium on Society & Resource Mgmt Bellingham, WA	Dave Dankel	60
19JUN00	Associated Engineers Spokane, WA	Greg Graham	35
18-19JUL00	Deputy ASA CW & General Counsel Tour McNary & LGR Dams	Jim Athearn	5
27JUL00	Inland Waterways Users Board - Portland, OR	Greg Graham	50
8AUG00	Elderhostel – Lewis & Clark State College Lewiston, ID	Chris Pinney	24
15AUG00	Idaho Food Producers Tour LGR Dam, WA	Mike Mason	17
17AUG00	Pacific Northwest Generating Coop Power Tour LGR Dam, WA	Greg Graham	18

DATE	GROUP/LOCATION	PRESENTER	AUDIENCE
11OCT00	Leadership Walla Walla Walla Walla, WA	Greg Graham	25
19OCT00	American Society of Civil Engineers – National Meeting Seattle, WA	Greg Graham	75
24OCT00	NW Salmonid Recovery Workshop	Greg Graham	120
29NOV00	Rotary Yakima	Greg Graham	80

LOWER SNAKE RIVER JUVENILE SALMON MIGRATION FEASIBILITY STUDY
2001 OUTREACH

DATE	GROUP/LOCATION	PRESENTER	AUDIENCE
17JAN01	Women's Study Group Walla Walla, WA	Dave Dankel	12
15FEB01	Whitman College Environmental Issues Walla Walla, WA	Dave Dankel	41
6MAR01	Jordanian Officials Tour LGR Dam, WA	Dave Dankel	7
4APR01	Engineer's Wives Club Walla Walla, WA	Dave Dankel	20
7APR01	NATO Representatives Tour LGR Dam, WA	Duane Meier	40
3MAY01	Idaho Gov. Conference on Recreation and Tourism Tour LGR Dam, WA	Greg Graham	30
22MAY01	Huxley College-WWU Environmental Regs Class Environemental Law Class Bellingham, WA	Dave Dankel	 65 20
24MAY01	Speakers Series -McNary Dam, Umatilla, OR	Dave Dankel	15
21JUN01	Whitman College Alumni Walla Walla, WA	Dave Dankel	60

DATE	GROUP/LOCATION	PRESENTER	AUDIENCE
7AUG01	Japanese Officials Portland, OR	Lonnie Mettler	4
10OCT01	Leadership Walla Walla Walla Walla, WA	Lonnie Mettler	21

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Annex E

Video Presentation Feedback Form

US Army Corps
of Engineers
Walla Walla District

"PATH OF THE SALMON"

Video Presentation Feedback Form

Date of showing (s):____________________ Location:____________________

Total number of viewers:_____________ Presenter:____________________

List any comments, questions, or issues that were brought up after the video was shown.

1.

2.

3.

4.

Do most viewers seem to be interested in salmon recovery efforts?

Other Comments:

For further information on the lower Snake River Juvenile Salmon Migration Feasibility Study, contact:

RETURN FORM TO:

U.S. Army Corps of Engineers
201 N. Third Ave
Walla Walla, WA 99362-1876
ATTN: Dave Dankel
Telephone 509-527-7288
(E-Mail) salmonstudy@usace.army.mil

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US Army Corps
of Engineers®
Walla Walla District

Final

Lower Snake River Juvenile Salmon Migration Feasibility Report/ Environmental Impact Statement

Appendix P

Air Quality

February 2002

US Army Corps
of Engineers®
Walla Walla District

Final
Lower Snake River Juvenile Salmon Migration Feasibility Report/ Environmental Impact Statement

Appendix P
Air Quality

Produced by

Kennedy/Jenks Consultants

Produced for

U.S. Army Corps of Engineers
Walla Walla District

February 2002

FOREWORD

Appendix P was prepared by Kennedy/Jenks Consultants in conjunction with the U.S. Army Corps of Engineers' (Corps) study team. Foster Wheeler Environmental Corporation also contributed to this appendix. In addition, the air quality analysis required extensive input from the Transportation and Power studies by the Drawdown Regional Economic Workgroup (DREW) that were undertaken as part of Appendix I, Economics. This appendix is one part of the overall effort of the Corps to prepare the Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement (FR/EIS).

The Corps has reached out to regional stakeholders (Federal agencies, tribes, states, local governmental entities, organizations, and individuals) during the development of the FR/EIS and appendices. This effort resulted in many of these regional stakeholders providing input and comments, and even drafting work products or portions of these documents. This regional input provided the Corps with an insight and perspective not found in previous processes. A great deal of this information was subsequently included in the FR/EIS and appendices; therefore, not all of the opinions and/or findings herein may reflect the official policy or position of the Corps.

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ACRONYMS AND ABBREVIATIONS

°C	degrees Celsius
°F	degrees Fahrenheit
$\mu g/m^3$	micrograms per cubic meter
AAQS	ambient air quality standards
aMW	average megawatt
ASIL	Acceptable Source Impact Level
BACT	best available control technology
BGS	Behavioral Guidance System
BPA	Bonneville Power Administration
Btu	British thermal unit
CAM	compliance assurance monitoring
CCAP	U.S. Climate Change Action Plan
CEMS	continuous emission monitoring system
CFC	chlorofluorocarbons
CFR	Code of Federal Regulations
CH_4	methane
cm	centimeter
CO	carbon monoxide
CO_2	carbon dioxide
Comp Plan	Lower Snake River Fish and Wildlife Compensation Plan
Corps	U.S. Army Corps of Engineers
CP^3	Columbia Plateau PM_{10} Program
DDT	1,1,1-trichloro-2,2-bis(p-chlorophenyl)-ethane
DREW	Drawdown Regional Economic Workgroup
EC	energy consumption
Ecology	Washington State Department of Ecology
EF	emission factor
EFSEC	Washington State Energy Facility Siting Evaluation Council
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
ESBS	extended submersible bar screen
EWITS	Eastern Washington Intermodal Transportation Study
FCAA	Federal Clean Air Act
FCCC	Framework Convention on Climate Change
Feasibility Study	Lower Snake River Juvenile Salmon Migration Feasibility Study
FR/EIS	Lower Snake River Juvenile Salmon Feasibility Report/ Environmental Impact Statement
g	gram
gal	gallon
GAMS	General Algebraic Modeling System
GHG	greenhouse gas
GIS	geographic information system
$g/sec\text{-}m^2$	grams per second per square meter

ACRONYMS AND ABBREVIATIONS

HAP	hazardous air pollutant
HCFC	partially halogenated fluorocarbons
HMU	Habitat Management Unit
hp	horsepower
HRSG	heat recovery steam generator
IPCC	Intergovernmental Panel on Climate Change
IPP	independent power producer
ISC	Industrial Source Complex
k	dimensionless aerodynamic particle size multiplier
kg	kilogram
kg/hour	kilograms per hour
km	kilometer
km/hour	kilometers per hour
LAER	lowest achievable emission rate
lb	pound
lb/gal	pounds per gallon
m	meter
M	moisture content
m/s	meters per second
m^2	square meter
m^3	cubic meter
mm	millimeter
mph	miles per hour
MT	metric ton (1,000 kg)
MTY	metric tons per year
MW	megawatt
N_2O	nitrous oxide
NCDC	National Climatic Data Center
NESHAP	National Emission Standards for Hazardous Air Pollutants
NH_3	ammonia
NMFS	National Marine Fisheries Service
NO_2	nitrogen dioxide
NOAA	National Oceanic and Atmospheric Administration
NOC	Notice of Construction
NROC	Natural Resources Defense Council
NWPPC	Northwest Power Planning Council
NO_x	nitrogen oxides
NSR	New Source Review
O_3	ozone
ODEQ	Oregon Department of Environmental Quality
p	number of days per year with measurable precipitation
Pb	lead
PG&E	Pacific Gas and Electric Company
PM	particulate matter

ACRONYMS AND ABBREVIATIONS

PM_{10}	particulate matter with aerodynamic diameters less than 10 micrometers
$PM_{2.5}$	particulate matter with aerodynamic diameters less than 2.5 micrometers
ppm	parts per million
ppmv	parts per million by volume
PROSYM	power system model
PSD	prevention of significant deterioration
RM	River Mile
S	mean vehicle speed
s	silt content
SBC	surface bypass collector
SCE	Southern California Edison
SCR	selective catalytic reduction
SDG&E	San Diego Gas and Electric
SEPA	Washington State Environmental Policy Act
SIP	Washington State Implementation Plan
SO_2	sulfur dioxide
SOR	system operation review
SR	state route
TAP	toxic air pollutant
TPY	tons per year
TSP	total suspended particulates
u	mean wind speed
u_{fm}	fastest mile
u_{fv}	frictional velocity
u_{tv}	threshold frictional velocity
VKT	vehicle kilometers traveled
VM	vehicle miles
VMT	vehicle miles traveled
VOC	volatile organic compound
W	mean vehicle weight
WAC	Washington Administrative Code
WEAQP	Wind Erosion Air Quality Project
WSCC	Western Systems Coordinating Council
WSDOT	Washington State Department of Transportation
yd	yard
yd^3	cubic yard

ENGLISH TO METRIC CONVERSION FACTORS

To Convert From	To	Multiply By
LENGTH CONVERSIONS:		
Inches	Millimeters	25.4
Feet	Meters	0.3048
Miles	Kilometers	1.6093
AREA CONVERSIONS:		
Acres	Hectares	0.4047
Acres	Square meters	4047
Square Miles	Square kilometers	2.590
VOLUME CONVERSIONS:		
Gallons	Cubic meters	0.003785
Cubic yards	Cubic meters	0.7646
Acre-feet	Hectare-meters	0.1234
Acre-feet	Cubic meters	1234
OTHER CONVERSIONS:		
Feet/mile	Meters/kilometer	0.1894
Tons	Kilograms	907.2
Tons/square mile	Kilograms/square kilometer	350.2703
Cubic feet/second	Cubic meters/sec	0.02832
Degrees Fahrenheit	Degrees Celsius	(Deg F –32) x (5/9)

Executive Summary

In response to the National Marine Fisheries Service 1995 Biological Opinion concerning the operation of the Federal Columbia River Power System, the U.S. Army Corps of Engineers is studying structural and operational alternatives to improve the downstream migration of juvenile salmon through the lower Snake River dams. The four alternatives that the U.S. Army Corps of Engineers is considering are:

- Alternative 1—Existing Conditions
- Alternative 2—Maximum Transport of Juvenile Fish
- Alternative 3—Major System Improvements
- Alternative 4—Dam Breaching.

From an air quality perspective, there is no difference in the impacts of the second and third alternatives. Accordingly, these two alternatives have been combined, and the following three air quality alternatives are evaluated:

- Existing Conditions—corresponding to Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement (FR/EIS) Alternative 1
- Major System Improvements—corresponding to FR/EIS Alternatives 2 and 3
- Dam Breaching—corresponding to FR/EIS Alternative 4.

Implementation of any of the proposed alternatives would affect air quality in the lower Snake River area. The information in this appendix may be used to compare the Lower Snake River Juvenile Salmon Migration FR/EIS alternatives from an air quality perspective and may be used with other investigations to develop a comprehensive picture of the consequences of the alternatives.

The Existing Conditions alternative represents current conditions during a base line year (generally 2010). The Major System Improvements alternative represents the base line year following structural enhancements to improve fish migration. The greatest change in emissions would be associated with the Dam Breaching alternative. Air quality issues associated with the Dam Breaching alternative include the following:

- Fugitive dust emissions generated during deconstruction of the dams
- A change in the quantity and distribution of vehicle emissions as Snake River commerce shifts from barges to trains and trucks
- Fugitive emissions resulting from dry exposed lake sediments during storm-generated high wind speeds
- Atmospheric emissions from new thermal power plants built to replace lost hydropower generating capacity.

Air quality issues associated with this alternative define the areas to be investigated. These same areas are investigated for the other alternatives to define base line conditions. The technical sections

of this appendix present and summarize each of these four issues by alternative. The summary below describes these emissions issues, organized by alternative.

Construction and Deconstruction Fugitive Dust

The Existing Conditions alternative would not result in demolition of the lower Snake River dams. Therefore, there would not be any fugitive dust emissions from deconstruction. Although the dams would remain intact for the Major System Improvements alternative, there would be some construction activities. Construction-related emissions would be very small and would be limited to particulate matter, which has been conservatively estimated at 907.2 kilograms (kg) per year (1 ton per year [TPY]). Construction equipment tailpipe emissions were not estimated.

The Dam Breaching alternative would result in deconstruction of the four lower Snake River dams. Deconstruction-related emissions for this alternative include fugitive emissions from material handling activities such as hauling, dumping, bulldozing, and grading. The emission estimates for particulate matter with aerodynamic diameters of less than 10 micrometers (PM_{10}) were derived from EPA emission factors, equipment operating hours, and the volume of material to be excavated. They account for construction mitigation measures such as spraying haul roads with water. The PM_{10} emissions of 1,193 tons were estimated by assuming that demolition of all four dams would take place in 1 year. This is a conservative assumption. The Drawdown Engineering Appendix (Appendix D) calls for a 2-year deconstruction schedule. Construction vehicle tailpipe emissions were not estimated.

The air quality analysis predicted ambient PM_{10} concentrations resulting from haul road fugitive dust emissions. The Lower Monumental stockpile haul road and the haul road for one of the three quarries were modeled using worst-case meteorology and EPA dispersion models. The proposed Lower Monumental excavation schedule is very short, resulting in the largest haul road emissions. Predicted PM_{10} concentrations are less than the Ambient Air Quality Standards (AAQS) within a short distance from the haul road. The area of restricted public access will be defined before deconstruction begins. Deconstruction emissions were also modeled to determine impacts in the Wallula nonattainment area, located about 18 kilometers (km) (11 miles) south-southwest of Ice Harbor. Predicted 24-hour PM_{10} concentrations were less than the 5 micrograms per cubic meter ($\mu g/m^3$) significance level. Emissions from dam deconstruction would not be allowed to delay the date for obtaining attainment status in the Wallala nonattainment area or to contribute to an air quality standard violation (WAC 173-400-113). This requirement is satisfied if the predicted concentrations are less than the significance levels. Nonattainment area concentrations greater than the significance levels require the source to offset its emissions.

Transportation Emissions

In 1994, more than 3.8 million metric tons (4.2 million tons) of freight passed through the Ice Harbor locks. About 80 percent of the river commerce is the downriver transportation of farm products, particularly grain. The Dam Breaching alternative would shift this commerce from barges to trains and trucks. Locomotive and truck emissions would replace Snake River towboat emissions.

Transportation-related emissions were estimated by modeling the movement of grain from farms through intermediate elevators to barges, trains, and trucks. EPA emission factors were used to convert bushel-miles or ton-miles predicted by the models to tons of emitted pollutants. The emission estimates were increased to account for all commodities (not just grain), increases in

commerce by 2010, and the return of empty containers. Transportation-related emissions for the Existing Conditions and Major System Improvements alternatives would represent base-case emissions for 2010. Dam Breaching alternative emissions are for 2010 without the Snake River waterway. The estimated emissions and the change in emissions are as follows:

	Emissions (tons)				
Pollutant	CO	NO_x	PM_{10}	SO_2	VOC
Existing Conditions	235	1,705	52	266	285
Major System Improvements	235	1,705	52	266	285
Percent Change from Existing Conditions	0	0	0	0	0
Dam Breaching	227	1,759	63	198	383
Percent Change from Existing Conditions	(3)	3	21	(26)	11

CO=carbon monxide, NO_x=nitrogen oxides, PM_{10}=particulate matter with aerodynamic diameters less than 10 micrometers, SO_2=sulfur dioxide, VOC=volatile organic compound.

Grain shipped on the Snake River is first trucked to elevators at river ports. Without the Snake river waterway, the grain would be trucked to elevators located next to railroads or to other ports on the Columbia River. Without the waterway, truck traffic would become concentrated on roads that lead to and from the Tri-Cities, especially U.S. 395. Local and rural roads east of Pasco would also receive much of the increased truck traffic. The modeled number of bushels of grain on eastern Washington roads, with and without the Snake River waterway, may be used to estimate the change in the number of trucks on major eastern Washington highways. The total number of trucks required for the grain harvest and the average number of trucks per day, at selected intersections, are as follows:

		Total Number of Trucks[1/]		Number of Trucks Per Day			
Highway	Intersection	With Snake River Dams	Without Snake River Dams	Current	Change with Drawdown	Projected	Percent Change
US 395	SR 26	6,923	68,083	2,480	1,003	3,483	40
	SR 260	6,923	68,198	2,160	1,005	3,165	47
SR 127	SR 26	6,923	3,462	290	(57)	233	(20)
SR 195	SR 272	21,923	8,077	1,920	(227)	1,693	(12)
SR 26	SR 395	6,923	31,385	375	401	776	107
	SR 195	3,462	21,923	575	303	878	53
SR 260	West of 395	6,923	2,308	884	(76)	808	(9)
	East of 395	3,462	2,308	195	(19)	176	(10)

SR=State Route.
[1/] Total number of trucks per grain-harvesting season.

The greatest increase in truck traffic would take place along roads that are already heavily traveled. Traffic along highways used to haul grain to river ports would decrease. Truck traffic on some little-used roads may double.

All transportation-related emissions would continue to decline in the future as fuel efficiencies improve and national emissions standards become effective. Emissions standards for locomotives took effect in 2000. Emissions standards for compression-ignition marine engines are proposed to become effective in 2004. The first phase of a proposed strategy to reduce emissions from heavy-duty vehicles would become effective in 2004.

Vehicle emissions were modeled to determine transportation-related impacts. Towboat emissions for barges navigating the Snake River and moored at hard rock dolphins combined to produce ambient concentrations that are a small fraction of the AAQS. Vehicle traffic at the intersection of US 395 and State Route (SR) 260 was modeled to estimate the impacts associated with additional grain trucks following dam breaching. The impacts were maximized by assuming that grain shipments continue all year. The predicted concentrations increased by only several percent. The annual nitrogen oxides (NO_x) concentrations increased from 25 to 27 percent of the ambient air quality standard.

Windblown Fugitive Dust

Windblown dust would continue to be the major air quality problem in eastern Washington. Dust storms would continue to occur periodically in the region. Under the Existing Conditions and Major System Improvements alternatives, the dust sources would be rangeland, irrigated agricultural lands, and dry agricultural lands, including fallow lands and harvested lands with crop residue. The period when these lands are most susceptible to erosion is September through November, after harvesting is completed and before winter rains begin. During this period, about 10 storms per year can be expected to produce fugitive emissions of varying intensity.

The Columbia Plateau PM_{10} Program (CP^3) has studied windblown dust and agricultural practices that would reduce emissions. Four of the larger storms from 1990 through 1993 were modeled by CP^3 to estimate emissions during these events and the resulting fugitive dust concentrations. Particulate matter emitted from between 0.809 and 2.023 million hectares (2 and 5 million acres) ranged from 10,900 to 213,200 metric tons (12,000 to 235,000 tons) per event. Daily PM_{10} concentrations measured in the Kennewick and Spokane areas were between 126 and 1,166 $\mu g/m^3$ (the air quality standard is 150 $\mu g/m^3$). PM_{10} concentrations in the area of the Ice Harbor and Lower Monumental dams were predicted to be about 2,400 $\mu g/m^3$ during these storms.

The Dam Breaching alternative would eliminate the lower Snake River reservoirs, creating large areas of dry lake sediments. Until seeding could establish a vegetative cover, these sediments would be susceptible to wind erosion. If strong winds such as those modeled by CP^3 occurred when the dry reservoir sediments were unprotected, PM_{10} emissions of between 354 and 3,520 metric tons (390 and 3,880 tons) per storm could be expected. These emissions would be 0.4 to 13 percent of the total emissions from agricultural lands.

Many individual storms would produce less than 181 metric tons (200 tons) of PM_{10} from all four dry reservoirs. All four dry reservoirs exposed for 1 year would emit about 5,706 metric tons (6,290 tons) of PM_{10}. These estimates include mitigation through seeding. Tests at Owens Lake in California indicate that a 99 percent emissions reduction is possible by covering only 50 percent of the dry sediments with vegetation. Three phases of drill seeding would follow the initial application of seed and fertilizer by aerial methods. The Corps would take measures to prohibit recreational vehicles on the dry sediments from breaking the surface crust and causing more material to be susceptible to erosion. The emission estimates include a 90 percent reduction factor for mitigation.

The CP^3 modeled PM_{10} emitted during several eastern Washington dust storms and calibrated the results with measured concentrations. This effort indicated that 24-hour concentrations in the region between Kennewick and Spokane can be much more than 150 $\mu g/m^3$, the AAQS. Land use and soil type data used in the modeling were recently modified to simulate the dry Snake River reservoirs. One storm event previously analyzed was remodeled. This analysis indicates that although the dry

reservoirs will be subject to wind erosion, the additional concentrations resulting from lake sediments will be much less than the AAQS. PM_{10} concentrations in eastern Washington will continue to exceed the AAQS. It is possible that portions of eastern Washington may be reclassified as nonattainment. If areas adjacent to the reservoirs are reclassified as nonattainment, impacts associated with wind blown dust from dry sediments could be significant and will need to be reevaluated.

Water quality studies (Appendix C) indicated that some sediments contain contaminants, particularly metals, dioxin, and DDT. Fugitive dust originating from these sediments will contain the contaminants. Exposure to contaminants at concentrations equal to their Acceptable Source Impact Level (ASIL), established by the Washington State Department of Ecology, will result in health risks of less than 1 in 1,000,000. The measured sediment contaminant concentrations would result in ambient concentrations less than ASILs, assuming that the contaminant concentrations in all exposed sediments are equal to the maximum measured concentration.

Replacement Power Emissions

Demand for power will continue to increase in the future regardless of actions taken at the Snake River dams, requiring additional generating capacity. Under the Existing Conditions and Major System Improvements alternatives, hydropower would continue to be available from the lower Snake River Dams. Under the Dam Breaching alternative, hydropower would no longer be available from the lower Snake River dams. The loss of these dams would affect the generating resources of the Western System Coordinating Council (WSCC), which includes the roughly 2,000 existing electrical generating units in the western United States. The Technical Report on Hydropower Costs and Benefits evaluated the need for additional generating capacity throughout the WSCC. Annual emissions from approximately 2,000 generating units were estimated from the number of hours each unit was projected to operate. The emission estimates represent the year 2010 and include additional natural-gas-fired, combined-cycle power plants. Carbon dioxide (CO_2), carbon monoxide (CO), PM_{10}, volatile organic compounds (VOCs), benzene, and formaldehyde emissions were estimated from the projected emissions and EPA emission factors for various fuels.

The Dam Breaching alternative includes two sub-alternatives. Under the New Power Plants scenario, new fossil-fuel power plants would replace all of the hydropower lost from the Lower Snake River dams. Under the Zero Carbon scenario, the lost hydropower would be replaced by implementing regional energy conservation measures and constructing new power plants that use nonpolluting renewable energy. The Hydropower Costs and Benefits Report evaluated costs associated with replacing power generated by the lower Snake River dams and concluded that it is not necessary to replace all 3,500 MW of peak generating capacity because the actual average annual power output from the dams is about 1,200 MW. The most likely scenario with dam breaching is construction of 1,550 MW of generating capacity somewhere in the Pacific Northwest by 2010.

The thermal power plants recently added to the WSCC have been predominantly natural-gas-fired, combined-cycle plants with combustion turbines. Nine of these plants have been constructed in Oregon and Washington since 1991, and another seven are planned. Because of their low cost, abundance of suitable sites, and favorable technical characteristics, natural-gas-fired, combined-cycle plants are the most likely power plants to be built in the near future (based on the year 2000 energy market). The hydropower study team concluded that for the New Power Plants

scenario, six new combined-cycle power plants (each with a 250 MW peak capacity) would be constructed in Washington or Oregon as replacement power under dam breaching.

Replacement power plants would likely share many of the characteristics of recently constructed and planned power plants. The emission characteristics for the replacement power plants were evaluated by inspecting the air quality permits for two actual power plants that have recently been permitted in Washington: a 248 MW plant near Vancouver and a 660 MW plant near Bellingham. New power plants would be subject to state and local air quality permitting and must demonstrate the use of best available control technology (BACT). Turbine emissions would be controlled by several technologies. NO_x control is obtained by using low NO_x burners and selective catalytic reduction (SCR). CO, VOC, and hazardous air pollutants are controlled by good combustion and a catalytic oxidation system. PM_{10} and sulfur dioxide (SO_2) emissions are controlled by using clean fuels such as natural gas and limiting the amount of fuel oil that can be used as backup fuel each year. This combination of emission controls satisfies BACT, and would also satisfy the National Emission Standards for Hazardous Air Pollutants (NESHAP), which EPA will soon propose for combustion turbines. Average annual emissions from the representative power plants would be as follows:

	Annual Emissions from Each 250 MW Combined-Cycle Power Plant						
	CO	NO_x	PM_{10}	SO_2	VOC	Ammonia	Formaldehyde
Emissions (tons/year)	88	99	41	48	30	93	0.5

Local ambient air pollutant concentrations within a few miles of each power plant were evaluated based on inspecting the air quality permits for the two representative actual power plants. The concentrations for all pollutants from the two actual power plants were all lower than the national, state, and local ambient air quality limits.

Total regional emissions for the Existing Conditions alternative and the Dam Breaching alternative were estimated for all of the roughly 2,000 generating units in the WSCC. Estimated emissions for each alternative and the change in emissions with the two Dam Breaching scenarios are as follows:

	Year 2010 Emissions in WSCC (thousands of tons per year)							
	CO	CO_2	NO_x	PM_{10}	SO_2	VOC	Benzene	Formaldehyde
Alternative								
Existing Conditions	404	414,234	57.8	49	457	1	0.004	0.04
Major System Improvements	404	414,234	57.8	49	457	1	0.004	0.04
New Power Plants	408	418,870	58.1	49	459	1	0.004	0.04
Zero Carbon	404	414,234	57.8	49	457	1	0.004	0.04
Increase for New Power Plants (%)	1.0	1.1	0.5	0.4	0.4	0.2	0.4	0.005
Increase for Zero Carbon (%)	0	0	0	0	0	0	0	0

Nationwide and regional CO_2 emissions are important because of possible impacts to global warming. In the 8-year period from 1990 to 1998, U.S. CO_2 emissions increased by about 11 percent, from 9,806 million to 10,932 million metric tons (10,809 to 12,050 million tons). If greenhouse gas emissions continue to increase at this rate, nationwide CO_2 emissions will reach 12,519 million metric tons (13,800 million tons) by 2010. The replacement power plants for the New Power Plants scenario could increase regional CO_2 emissions by 4.6 million tons per year. That increase would be equivalent to 1.1 percent of the total CO_2 emissions within the WSCC and

would be 0.14 percent of the nationwide CO_2 emission increase during the planning period 1990-2010.

Under the Zero Carbon scenario, the hydropower lost from the Lower Snake River dams would be replaced by conservation measures and development of nonpolluting renewable energy resources. The required energy conservation measures would be equivalent to 5.3 percent of the total electrical demand in the WSCC region for the year 2010. There would be no net increase in CO_2 emissions under the Zero Carbon scenario.

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1. Introduction: Scope and Issues Development

The Lower Snake River Juvenile Salmon Migration Feasibility Study (Feasibility Study) assessed the measures intended to facilitate migration of juvenile salmon through the lower Snake River. Implementation of the proposed measures would result in air quality-related effects. The purpose of this air quality appendix is to estimate changes in air pollutant concentrations associated with the Feasibility Study alternatives and to qualitatively evaluate indirect impacts associated with dam breaching. In several instances, emission sources are located in airsheds other than along the lower Snake River.

To evaluate air quality impacts, the alternatives considered in the Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement (FR/EIS) were used to create alternatives for the air quality investigation. Although the FR/EIS identifies four alternatives, the air quality impacts of FR/EIS Alternatives 2 and 3 are almost identical. The evaluations of Alternatives 2 and 3 are therefore combined in this appendix, yielding the following three air quality investigation alternatives:

- Existing Conditions (FR/EIS Alternative 1)—The status of the lower Snake River reservoirs and hydrofacilities would remain unchanged. Emissions estimated for this alternative represent current conditions for a base line year.
- Major System Improvements (FR/EIS Alternatives 2 and 3)—Collection and bypass structures would be constructed at all hydropower facilities to enhance fish passage. Barge transportation and power generation would continue with little change.
- Dam Breaching (FR/EIS Alternative 4)—The four lower Snake River hydropower facilities would be breached, restoring the river to near-natural conditions. Barge transportation and hydropower would be replaced with other sources of transportation and power generation.
- The air quality issues related to the Lower Snake River Juvenile Salmon Migration Feasibility Study alternatives are:
- Fugitive dust emissions resulting from deconstruction of the dams
- Changes in the quantity and distribution of vehicle emissions as commodities are shifted from barges to trains and trucks
- Fugitive dust emissions resulting from dry exposed lake sediments during high wind speed events
- Atmospheric emissions associated with replacement power generation by thermal power plants.

Cumulative impacts evaluated in this analysis include the effects of breaching all four dams in one year and building all replacement power plants at once. Some impacts associated with indirect effects are subject to socioeconomic conditions and factors that are beyond the scope of this assessment. This appendix contains seven sections. Section 1 summarizes the air quality issues

associated with the Feasibility Study and provides an overview of the study process. Section 2 describes the air quality of the lower Snake River area, including the Federal and state programs that regulate air quality in the region of the lower Snake River and the air quality standards relevant to the analysis. The climatology and existing air quality of the region are also described. Section 3 presents the methods that this study uses for the air quality analysis. Section 4 presents the study results for the Feasibility Study alternatives and potential mitigation measures. Section 5 compares the air quality impacts of the alternatives. Sections 6 and 7 contain the references and glossary, respectively. Technical annexes A through D support the analysis and are included.

1.1 Issues Raised During the Scoping Process

The multi-agency System Operation Review (SOR) of the Columbia and Snake rivers included an analysis of the consequences to air quality resulting from the annual or permanent drawdown of reservoirs (Bonneville Power Administration [BPA], U.S. Army Corps of Engineers [Corps], and Bureau of Reclamation, 1995, SOR Appendix B). This analysis builds on the SOR work while focusing on the four lower Snake River dams. Some of the air quality issues identified during the SOR have been carried over to this study.

A number of additional air quality issues related to the Dam Breaching alternative have been identified, including the following:

- Cumulative impacts of new and existing power plants
- Greenhouse gases (GHG) and hazardous air pollutants (HAP) from replacement power generation
- Site-specific data for characterizing air quality impacts
- Mobile source emission impacts on existing highways and roadways
- Cumulative impacts of demolishing more than one dam at a time
- Contaminants potentially present in reservoir sediments that may become airborne during dust storms.

The objective of this appendix is to provide a basis to compare impacts of the Feasibility Study pathways from an air quality perspective. This is accomplished by estimating air emissions resulting from pathway-related activities. Air emissions that result from pathway-related activities are subject to applicable local, state, and Federal air quality regulations. In the case of power plants constructed to replace lost hydropower, the emissions and corresponding ambient concentrations are defined in this Appendix by examples obtained from recently permitted projects. Three recently permitted power plants in the Pacific Northwest may be constructed as demand for power rises. Projected emissions and predicted concentrations from these projects are included in this analysis. Additional power plants may be needed if the lower Snake River hydropower plants are removed. According to the Power System Analysis (DREW, 1999a), some new thermal power plants would be sited for power grid stability. Other power plants would be sited according to resource (natural gas, wind) availability, proximity to transmission lines, power demand, and environmental considerations. Data required for a detailed impact analysis suitable for air emissions permit applications includes, at a minimum, the size and location of the replacement power plants. These

data will not be known for many years. A detailed analysis that includes these hypothetical plants and the cumulative impacts of all the new power plants is not possible at this time.

If the Dam Breaching alternative is selected, more in-depth analysis and data collection would be pursued in the following air quality areas:

- A configuration of the sources
- The schedule and duration of the deconstruction, drawdown, and revegetation (A spring drawdown and revegetation would produce fewer emissions.)
- The potential population at risk from emissions
- Site-specific data including meteorological data suitable for dispersion modeling, silt and moisture content of the excavated material and dry sediments, and the surface extent of contaminated sediments.

The concentrations and locations of contaminated sediments have only recently been made available. The data, however, are averages of the top 0.6096 meter (2 feet) of sediments, not sediment surface concentrations. This analysis evaluated fugitive emissions of contaminated sediments by assuming worst-case sediment concentrations. Additional work in this area may be necessary.

To the extent possible, GHG and HAP emissions have been incorporated into the air quality analysis.

1.2 The Study Process

Air quality is not a major resource use of the lower Snake River. Consequently, the air quality study process differed from that of most of the other resource topics. Although the air quality analysis required little coordination with the other work groups, the analysis did require input from a number of other study groups. The Transportation Analysis (DREW, 1999b) provided transportation miles for calculating vehicle emissions. The Power System Analysis (DREW, 1999a) provided existing and projected emissions for thermal power plants. The Existing Systems and Major System Improvements Engineering Appendix (Appendix E) provides descriptions of construction activities planned for the Major System Improvements. The Natural River Drawdown Engineering Appendix (Appendix D) provides excavation quantities, a description of the plan to seed the reservoirs to develop ground cover, and a comprehensive list of equipment and hourly usage.

Data from independent studies were used in this analysis. The Columbia Plateau PM_{10} Program, part of the Wind Erosion Air Quality Project, and the Eastern Washington Intermodal Transportation Study were extensively referenced in this analysis. Environmental Protection Agency (EPA) data, emission factors, and dispersion models contributed to the impact analysis.

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2. Air Quality of the Lower Snake River

This chapter describes the affected regional air quality and meteorological environment of the lower Snake River. Federal and state air quality programs and the air quality standards that pertain to the Lower Snake River Juvenile Salmon Mitigation Feasibility Study are summarized in Section 2.1. Section 2.2 provides an overview of existing emission sources and air quality in the region. Section 2.3 addresses climatic factors that are relevant to the air quality analysis.

2.1 Air Quality Management

2.1.1 Regulated Air Pollutants

The Federal Clean Air Act (FCAA) requires the EPA to set AAQS to protect the public health and welfare. Standards to protect public health (primary standards) must provide for the most sensitive individuals and allow a margin of safety, without regard to the cost of achieving the standards. Secondary standards protect public welfare (e.g., crop damage, tire oxidation) rather than public health. Air quality standards have been established for CO, lead (Pb), PM_{10}, NO_2, ozone (O_3), and SO_2.

Primary and secondary standards have been established for particulate matter that can be respired by humans. The original standards for total suspended particulate matter (TSP), defined as all particulate matter released into the atmosphere, were revised in 1987, when standards for PM_{10} were also established. PM_{10} can penetrate deep into the respiratory tract and lead to a variety of respiratory problems and illnesses. A number of published studies suggest that the number of cases of premature mortality, hospital admissions, and respiratory illnesses increases as the ambient PM_{10} concentration increases.

In 1997 EPA revised the particulate matter standards by adopting new standards for particles smaller than 2.5 micrometers ($PM_{2.5}$). EPA has retained the annual PM_{10} standard and adjusted the 24-hour standard until implementation strategies can be put into place. EPA has issued rules related to particulate matter monitoring requirements under the new standard. Washington is currently monitoring $PM_{2.5}$ concentrations throughout the state and will propose $PM_{2.5}$ nonattainment areas in the year 2001; nonattainment areas are areas that do not comply with the standard.

Although the Federal government no longer regulates TSP, several states (including Washington) maintain TSP standards, in part to address nuisance dust problems. The Washington State Department of Ecology (Ecology) enforces both TSP and PM_{10} standards and intends to adopt $PM_{2.5}$ standards similar to the Federal standards of an annual average of 15 micrograms per cubic meter ($\mu g/m^3$) and a 24-hour average of 65 $\mu g/m^3$.

EPA also revised the ozone standard in 1997, provided guidance for implementation of the regional haze regulations, and provided for a transition period to the new standard. The ozone standard is expressed as a 3-year average of the annual fourth highest daily maximum 8-hour ozone concentration and is set at 0.08 parts per million (ppm). Ecology will retain the 1-hour 0.12 ppm standard until it adopts new regulations.

EPA has delegated several air quality regulatory responsibilities to state and local agencies. State and local responsibilities include enforcing national and state AAQS, assuring human health

protection from toxic air pollutants (TAPs), and mitigating nuisances caused by windblown dust. Standards of the State of Oregon Department of Environmental Quality (DEQ) are similar to the Washington standards. Applicable AAQS are found in Table 2-1.

Table 2-1. Ambient Air Quality Standards

Pollutant	National Primary	National Secondary	Idaho	Oregon	Washington
Proposed fine particulate matter ($PM_{2.5}$) ($\mu g/m^3$)					
Annual arithmetic average	15	15			
24-hour average	65	65			
fine particulate matter (PM_{10}) ($\mu g/m^3$)					
Annual arithmetic average	50	50	50	50	50
24-hour average1/	150	150	150	150	150
Total suspended particulates (TSP) ($\mu g/m^3$)					
Annual geometric average				60	60
24-hour average1/				150	150
Carbon monoxide (ppmv)					
8-hour average	9	9	9	9	9
1-hour average	35	35	35	35	35
Ozone (ppmv)					
Proposed 8-hour average	0.08	0.08			
1-hour average2/	0.12	0.12	0.12	0.12	0.12
Sulfur dioxide (ppmv)					
Annual average	0.03	0.02	0.03	0.02	0.02
24-hour average	0.14		0.14	0.10	0.10
3-hour average		0.50	0.50	0.50	
1-hour average3/					0.25
1-hour average					0.40
Lead ($\mu g/m^3$)					
Calendar quarter average	1.5		1.5	1.5	1.5
Nitrogen dioxide (ppmv)					
Annual average	0.053	0.053	0.053	0.053	0.05

Source: 40 CFR Part 50; IDAP 16.01.01.577; OAR 340-031; and WAC 173-470, -474, -475.

Notes: Annual standards are never to be exceeded, and shorter-term standards are not to be exceeded more than once per year unless noted.

ppm = parts per million; ppmv=parts per million by volume; ($\mu g/m^3$) = micrograms per cubic meter.

1/ Standard attained when expected number of days per year with a 24-hour concentration above 150 $\mu g/m^3$ is less than or equal to one.

2/ Standard attained when expected number of days per year with an hourly average above 0.12 ppm is less than or equal to one.

3/ Not to be exceeded more than twice in 2 days.

The EPA regulates HAP emissions through the National Emission Standard for Hazardous Air Pollutants (NESHAP). Combustion turbines are sources of small amounts of HAPs, particularly formaldehyde. Very large turbines, or groups of turbines, could emit individual HAPs in quantities greater than 9.1 metric tons (10 tons) per year, or all HAPs in quantities greater than 22.7 metric tons (25 tons) per year. As required by Title III of the FCAA, a NESHAP for combustion turbines is currently under development. The combustion turbine NESHAP will establish emission limits and control requirements and will probably become effective within 10 years (see http://www.epa.gov/ttn/uatw/mactprop.html).

The standards for toxic air pollution vary by state. Ecology regulates emissions of individual TAPs (Washington Administrative Code [WAC] 173-460). Many HAPs and TAPs are VOCs. Ecology's rule is to protect the public from exposure to unhealthy levels of toxic and cancer-causing emissions from new industrial sources. Ecology's TAP list is more extensive than the EPA's HAP list.

In 1999, litigation at the U.S. Court of Appeals for the District of Columbia involved EPA's setting of $PM_{2.5}$, O_3, and PM_{10} standards (American Trucking Associations vs. EPA, 175F.3d 1027 [D.C. Cir. 1999] and rehearing 195 F.3d 4 [D.C. Cir. 1999]). The timeline for implementation of the regional haze rule is tied to the schedule for implementation of the $PM_{2.5}$ standard.

2.1.2 Nonattainment Areas

Nonattainment areas are regions where agency-operated air quality monitors have shown frequent exceedances of the AAQS listed in Table 2-1. New emission sources that either are located inside nonattainment areas or that would adversely affect any nearby nonattainment area are subject to additional permitting requirements. For PM_{10} sources, the significance level is a 24-hour concentration equal to 5 $\mu g/m^3$. The nonattainment areas nearest the lower Snake River dams are as follows:

- Wallula, Washington, 18 km (11 miles) south-southwest of Cold Harbor Dam
- City of Spokane, 110 km (70 miles) north of Lower Granite Dam
- Pendleton, Oregon, 60 km (38 miles) south of Ice Harbor Dam.
- New emission sources that adversely affect a nonattainment area must provide the following emission reductions:
- Install emission controls to satisfy the Lowest Achievable Emission Rate (LAER)
- Provide emission offsets from offsite facilities equal to the emissions from the proposed new source.
- As described in Section 4.3 of this appendix, worst-case modeling has shown that none of the nearby nonattainment areas would be adversely affected by fugitive dust emissions from either dam breaching construction or the resulting dry lake beds.

2.1.3 Washington State Strategy for Large Sources of Windblown Dust

Windblown dust from agricultural areas in southeastern Washington is a major concern. Washington's general strategy for reducing fugitive dust emissions from large windblown dust sources is specified in the State Implementation Plan (SIP). The SIP includes estimates of current and future windblown dust emissions and outlines Ecology's plans to reduce emissions. The SIP also specifies locations where Ecology operates ambient air quality monitors and specifies existing nonattainment areas.

The SIP consists of EPA-approved state and local regulations governing air emissions and air quality (follow SIP-related link at http://www.ecy.wa.gov/programs/air/airhome.html).

Ecology currently operates only a few ambient monitors in the region. Even though all of the regional monitors have measured occasional exceedances of the PM_{10} AAQS, Ecology has

demonstrated that most of the exceedances result from unavoidable regional wind storms. Based on that demonstration, Ecology has established only a few PM_{10} nonattainment areas in the region, none of which appear to be relevant to the lower Snake River dams. However, discussions with Ecology staff (telephone conversation, Melissa McEachran, Washington Department of Ecology, and James Wilder, Kennedy/Jenks Consultants, November 22, 2000) indicate that Ecology proposes to begin PM_{10} monitoring at several new sites to evaluate widespread dust impacts on the Columbia River Plateau. Some of those new monitors will be near the Snake River dams. Ecology could use new monitoring data at the new sites to establish new PM_{10} nonattainment areas close enough to the dams to affect air quality permitting associated with dam breaching.

2.1.4 Air Quality Permitting for Construction Activities Related to Dam Breaching

Discussions with state regulatory agencies (telephone conversation, Doug Schneider, Washington Department of Ecology, and James Wilder, Kennedy/Jenks Consultants, December 5, 2000) indicated that few, if any, air quality permits would be required for the construction activities related to breaching the dams. Washington state air quality regulations exempt temporary construction activities from obtaining pre-construction air quality permits. However, it is assumed that the following conditions could be specified in any of the numerous construction, shoreline and grading permits that would be obtained for the project:

- Modeling to demonstrate that construction activities and the dry lake beds would not emit enough windblown dust to cause local exceedances of the AAQS
- Specific dust control measures for earthmoving and haul roads (e.g., use of palliatives for dust control on haul roads)
- Specific measures to reduce fugitive dust from the dry lake beds
- Installation of ambient air quality monitors during and following construction to evaluate fugitive dust impacts caused by the dry lake beds.

2.1.5 Air Quality Permitting for New Power Plants

The Dam Breaching alternative assumes construction of new power plants to replace hydropower lost from the lower Snake River dams. For this EIS, it is assumed that new combined-cycle gas turbine power plants would be constructed in either Washington or Oregon. The complexity of air quality permitting for any given power plant would depend on where the plant was located (Washington vs. Oregon) and on the size of the power plant (less than or more than 250 MW).

As described in Section 4.3.4 of this appendix, it is assumed that a combined-cycle gas turbine power plant less than 250 MW would emit less than 99 tons per year of NO_x. Electric utility power plants that emit less than 100 tons per year of any individual pollutant require only a conventional Notice of Construction (NOC) air quality permit and would not be subject to Prevention of Significant Deterioration (PSD) permitting. The requirements for a NOC permit would be as follows:

- Demonstrate that emissions are controlled with Best Available Control Technology (BACT). For a gas turbine power plant, this would require use of a low-NO_x turbine,

selective catalytic reduction (SCR) for NO_x control, an oxidation catalyst for CO control, and restrictions on the annual use of low-sulfur oil as a backup fuel

- Conduct computer dispersion modeling to demonstrate that emissions would not result in ambient concentrations greater than the AAQS or state limits on ambient concentrations of toxic air pollutants
- Undertake public participation.

New power plants larger than 250 MW would probably emit more than 100 tons per year of NO_x and would therefore be subject to PSD permitting and Federal Title V permitting. PSD permitting would require the same steps as listed above for a conventional NOC permit, plus the following additional requirements:

- Perform computer dispersion modeling to demonstrate that the power plant emissions would not increase the ambient concentrations by more than the allowable PSD increments. These PSD increments are much more stringent than the AAQS listed in Table 2-1. In the past, this demonstration has been relatively easy, even for large emission sources. Records searching is required to determine if any of the PSD increment above base line has been consumed by other sources.
- Perform computer modeling to demonstrate that the power plant would not significantly affect Air Quality Related Values (nitrate/sulfate deposition, impacts to vegetation and wildlife, and regional visibility) at protected Class I areas. Class I areas include wilderness areas, National Parks, and some Indian reservations. Large industrial sources sometimes have difficulty demonstrating that Air Quality Related Values resulting from their emissions are less than acceptable limits for these values. Therefore, it is likely that the developers of a new power plant larger than 250 MW would avoid constructing the plant within 100 km (62 miles) of any Class I area.

A Federal Title V air operating permit would be required for any power plant subject to PSD permitting. The Title V permit would probably specify the same emission limits, emission monitoring, and recordkeeping requirements that would be in the PSD permit. The Compliance Assurance Monitoring (CAM) section of the Title V permit would probably not require any additional emission monitoring beyond what would be specified in the PSD permit.

Any gas turbine power plant that emitted more than 10 tons per year of any individual HAP (or more than 25 tons per year of combined HAPs) would be subject to additional permitting under NESHAP. However, as described in Section 4.3.4. of this appendix, it is unlikely that even the largest replacement power plants would emit enough HAPs to trigger the NESHAP requirements. In any case, the BACT emission controls already required for power plants under conventional air quality permitting in Washington and Oregon are as stringent as any expected requirements under NESHAP.

Any power plant constructed in Oregon would have to reduce its CO_2 emissions to satisfy the state's unique CO_2 emission standard of 0.675 pounds per kw-hour. Based on data from power plant manufacturers, CO_2 emissions from a combined-cycle gas fired turbine plant would be about 0.83 pounds per kw-hr, which exceeds the Oregon limit. In that case, the power plant operator in Oregon would pay the state an emission fee of $0.57 per ton of CO_2 emissions exceeding the allowable

limit. It is also possible, but not required, that power plants constructed in Washington would agree to achieve Oregon's CO_2 emission limit or pay comparable emission fees as part of negotiated permit conditions developed as part of Washington's State Environmental Policy Act (SEPA) public review process.

2.1.6 Air Quality Conformity Requirements for Federally Funded Projects

The 1990 Clean Air Act Amendments include provisions for air quality conformity. Conformity requires that all Federally funded projects constructed in nonattainment areas conduct rigorous air quality evaluations to demonstrate that emissions will not cause additional exceedances within the nonattainment area. EPA's rationale for the conformity regulation is that many large Federal projects (e.g., new highways) were previously exempted from local air quality permitting, even though they might result in large emission increases and significant ambient air quality impacts.

Discussions with State of Washington regulatory staff (telephone conversation, Doug Schneider, Washington Department of Ecology, and James Wilder, Kennedy/Jenks Consultants, December 5, 2000) indicate that breaching of the lower Snake River dams would *not* be subject to air quality conformity requirements because none of the dams are located inside existing nonattainment areas. Therefore, the Federal conformity rules would not require any evaluation of fugitive dust or transportation impacts related to the lower Snake River dams. Any future evaluations of fugitive dust impacts on ambient air quality would have to be required as special permit conditions in construction permits (see Section 2.1.4).

2.1.7 Greenhouse Gases

Over the past 100 years, carbon dioxide levels in the atmosphere have increased by about 25 percent. Carbon dioxide concentrations will continue to increase as the world population grows and societies around the globe industrialize. The dynamics of the atmosphere, and thus the climate of the earth, are affected by changes in the ability of the atmosphere to retain heat. Heat retention is enhanced by increased concentrations of greenhouse gases (GHG).

The Intergovernmental Panel on Climate Change (IPCC) was established by the World Meteorological Organization and the United Nations Environment Programme in 1988 to assess the available scientific, technical, and socioeconomic information regarding climate change. A 1996 IPCC report concluded that:

> Our ability to quantify the human influence on global climate is currently limited because the expected signal is still emerging from the noise of natural variability, and because there are uncertainties in key factors. These include the magnitudes and patterns of long-term variability and the time-evolving pattern of forcing by, and response to, changes in concentrations of greenhouse gases and aerosols, and land surface changes. Nevertheless, the balance of evidence suggests that there is a discernible human influence on global climate (IPCC, 1996).

The text of the Framework Convention on Climate Change (FCCC) was adopted by the United Nations and opened for signature at Rio de Janeiro in 1992. At Rio de Janeiro the world's industrialized nations agreed to establish policies and measures that reduce emissions of the GHGs. The FCCC was signed by 150 nations, including the United States. To meet this pledge, President Clinton introduced the United States Climate Change Action Plan (CCAP) in October 1993. Its

main goal is to reduce United States GHG emissions to their 1990 levels by 2000. In 1997, representatives from more than 160 countries met in Kyoto, Japan, to negotiate binding limits on GHG emissions for developed nations. The target for the United States is 7 percent below 1990 levels (Energy Information Administration, 1998). Although global climate is influenced by GHG concentrations, the Kyoto Protocol establishes targets in terms of annual emissions. GHGs addressed by the protocol include CO_2, methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFCs), partially halogenated fluorocarbons (HCFCs), and O_3.

Under the CCAP, states play a critical role in reducing GHG emissions. EPA's State and Local Climate Change Outreach Program partners with states to create GHG inventories and action plans for individual states. Washington State's Action Plan has a goal of stabilizing GHG emissions through an 18-million-ton reduction from "business as usual" by 2010. In order to meet this goal, the GHG emissions associated with each proposed project should be analyzed for their impact on the State GHG inventory.

A GHG inventory is a prerequisite for evaluating the cost effectiveness and feasibility of mitigation strategies and reduction technologies. The air quality analysis in this appendix evaluates emissions from thermal power plants. This discussion will focus on CO_2, the principal GHG resulting from fossil fuel combustion.

Table 2-2 shows historical trends in CO_2 emissions in the United States as a whole, compared to CO_2 emissions in Washington and Oregon (EPA, 2000; Washington Community Trade and Economic Development, 1999; Oregon Office of Energy, 2000). As of 1998, the combined emissions from Oregon and Washington were a disproportionately small fraction of the nationwide total. The emissions from the two states were only 1.4 percent of the nationwide total, whereas the two states' populations are 4 percent of the nation's total. CO_2 emissions from the two states are disproportionately low because much of the regional electricity in the Pacific Northwest is produced by non-polluting hydropower. As listed in Table 2-2, fossil fuel combustion for transportation is the predominant source of CO_2 emissions in Washington and Oregon.

Section 4.3.4 of this appendix describes existing CO_2 emissions in the Pacific Northwest and estimates the future CO_2 emissions that would result under the Dam Breaching alternative.

2.2 Overview of Existing Air Quality

The air quality in the lower Snake River region generally continues to meet the AAQS. Components of the air quality environment include emission sources, ambient air pollutant concentrations as measured by a sampling network, and meteorological effects that govern the generation of windblown dust and the behavior of emitted industrial emissions. These influences are discussed below.

2.2.1 Sources of Air Emissions

Industrial operations, woodsmoke, road dust, and windblown dust from disturbed surfaces (such as agricultural fields) are the primary sources of fugitive particulate matter in the atmosphere. All of these sources are present in the lower Snake River region. Industrial emissions are the primary source of gaseous criteria air pollutants, TAPs, and GHGs.

Particulate sources within the basin include area sources (dirt or gravel roads and plowed fields) and industrial point sources (manufacturing plants). Area sources are subject to wind erosion that results

Table 2-2. Historical Carbon Dioxide Emissions

Emission Source Category	Nationwide United States CO_2 Emissions (millions of tons per year)		Combined Washington and Oregon CO_2 Emissions (millions of tons per year)	
	Year 1990	Year 1998	Year 1990	Year 1998
Electric utilities	3,848	4,434	27	39
Non-utility and residential power and heating	3,582	3,791	23	31
Transportation	3,227	3,630	67	80
Manufacturing and other sources	152	195	18	19
Total Emissions	**10,809**	**12,050**	**135**	**169**
Net Increase, 1990 – 1998	–	**1,241 (11%)**	–	**34 (25%)**

Data sources: Environmental Protection Agency, 2000a; Oregon Office of Energy, 2000; Washington Community Trade and Economic Development, 1999.

in blowing dust. Typical manufacturing plant emissions include soot and fine wood particles. Throughout the arid and semi-arid portions of eastern Washington, wind erosion is the primary cause of dust emissions, usually associated with dryland farming. Windblown emissions are also produced by irrigated agriculture and nonagricultural sources such as exposed reservoir shorelines. Similar conditions for particulate emissions apply to the Feasibility Study area. The Draft Environmental Impact Statement, Continued Development of the Columbia Basin Project, Washington, (Bureau of Reclamation, 1989) reported the following characterization for eastern Washington:

> Area sources are far more important than point sources because of the prevalence of wind erosion. Wind erosion is greatest during the spring and fall, when high winds and dry soil conditions create dust storms of varying severity. Highway and road closings are sometimes necessary because of reduced visibility. The severity of dust storms is exacerbated by dryland agricultural practices, which expose the soil during spring cultivation and fall harvesting.
>
> Annual total suspended particulate readings at Pasco, Washington (based on a 12-month moving geometric mean concentration) ranged from 45 to 65 $\mu g/m^3$ during the mid-1980s and in some years exceeded the Washington State annual standard of 60 $\mu g/m^3$. Over the same period, there were from 2 to 4 days per year on which particulate concentrations exceeded the 150 $\mu g/m^3$ standard for a 24-hour period.

These conditions and measurements apply specifically to eastern Washington agricultural areas. Extensive agricultural areas around or near the lower Snake River reservoirs will contribute to PM_{10} concentrations in the Snake River canyon, where there is limited disturbed land. PM_{10} concentrations along the river are likely to be smaller than in the agricultural and industrial areas.

Thermal power plants commonly emit CO, CO_2, NO_x, particulate matter (PM), and SO_2 as combustion byproducts. Air quality is a particular concern around these plants, and more stringent emission controls are required for existing facilities and new projects in these affected areas. All recent additions to Northwest thermal plant capacity have been natural gas-fired combined-cycle combustion turbines. These plants use the least-polluting carbon fuel in highly efficient engines, in which chemical emissions can be effectively controlled. Wind-powered turbines have very recently been added to the power-generating resources of the Pacific Northwest.

2.2.2 Major Industrial Sources of Air Emissions

Major industrial emission sources (emission rates greater than 90.7 metric tons (100 tons) per year [TPY]) within 50 kilometers (31 miles) of the four lower Snake River dams are located in Benton, Franklin, Walla Walla, and Whitman counties. Table 2-3 lists emissions data for local major sources (sources which emit less than 90.7 metric tons (100 tons) of a pollutant are not reported) in these counties, for the most recent reporting year available (EPA, 2000b).

As part of its review of the Washington Visibility Protection Plan, Ecology developed a county-by-county emissions inventory for 1996 (Ecology, 1999). This inventory is used to illustrate emission sources for counties adjacent to the lower Snake River (Figure 2-1). Figure 2-1 indicates that Benton and Whitman counties are the primary sources of CO and PM_{10} emissions, respectively. Investigation of the emissions by source category indicates that highway vehicles are the primary

source of CO and agricultural activities and unpaved roads are the primary sources of PM_{10} (Figure 2-2). Industrial emissions, indicated in Figure 2-2 by the Point Source category, constitute only a small fraction of the total emissions for the region.

Table 2-3. Major Air Emission Sources within the Region of the Lower Snake River

	Source		Emissions (TPY)			
County	City	Facility	NO_2	PM_{10}	SO_2	VOCs
Benton, WA	Plymouth	Northwest Pipeline	532			
	Benton City	A & B Asphalt		177		
	Kennewick	Harvest States Corp.	2,246	126		
		Unocal Agricultural Products				
	Richland	Acme Materials Construction		104		
		U.S. Energy Department	283		457	
Franklin, WA	Pasco	Tidewater Terminal				1,427
		Chevron Northeast Terminal				215
Walla Walla, WA	Starbucks	Pacific Gas Transmission	330			
	Wallula	Pacific Gas Transmission	326			
		Boise Cascade Wallula	1,080	348	1,995	913
	Walla Walla	Crown Cork & Seal				297
Whitman, WA	Pullman	Washington State University	240		191	
Lath, ID	Moscow	Potlatch Corp	133			

Source: Environmental Protection Agency, 2000b.
Notes: TPY=tons per year. Metric tons per year = TPY*0.907.

Ambient air quality monitoring is conducted in areas of known or suspected air quality problems. Because of traffic congestion, CO is monitored in the greater Puget Sound area [the traffic volume on Interstate 5 near the intersection of Interstate 90 is 264,000 vehicles per day (WSDOT, 2000)], Vancouver, Spokane, and Yakima. In eastern Washington, traffic volumes are relatively small, there are few large sources of industrial emissions, and the CO air quality standard is roughly 100 times higher than the PM_{10} standard. PM_{10} is the only pollutant of general concern in eastern Washington.

Historically, high CO and PM_{10} concentrations have been measured in Spokane. Major contributors to Spokane County CO emissions are vehicles, industrial sources (especially the aluminum industry), prescribed burning, and woodstoves (Ecology, 1999). Agricultural lands and unpaved roads are the primary sources of PM_{10} emissions in Spokane County (Ecology, 1999).

Collocated $PM_{2.5}$ and PM_{10} monitoring provides an opportunity to compare the composition of the particles (EPA, 1997a). Although collected in other parts of the United States (Arizona, California, Colorado, South Dakota, and other southern and eastern states), the collocated monitoring data are generally representative of the arid environment of the lower Snake River region. $PM_{2.5}$ is composed of particles emitted directly into the air and particles formed in the air from chemical transformation of gaseous pollutants (secondary particles). The principal types of secondary particles are created from the reaction of SO_2 and NO_x emissions with ammonia (NH_3). The principal types of directly emitted particles are soil particles and organic or elemental carbon particles from fossil fuel combustion and biomass materials. The soil particle component is low for $PM_{2.5}$ (5 to 15 percent, compared to about 50 percent for PM_{10}), but the combustion component is much higher (35 to 60 percent compared to about 15 to 23 percent for PM_{10}). The fraction of nitrates and sulfates in $PM_{2.5}$ is about 13 and 24 percent, respectively.

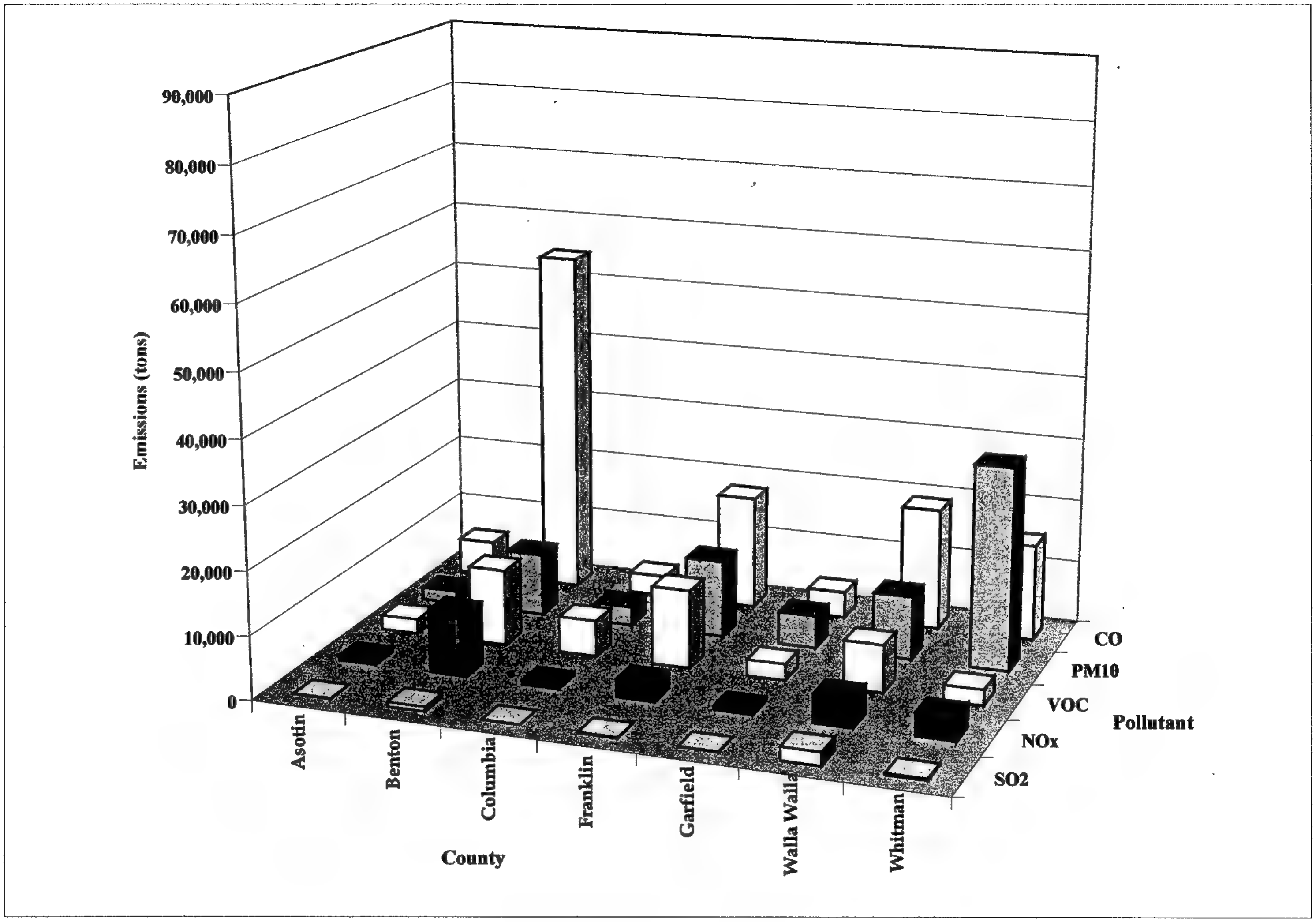

Figure 2-1. Atmospheric Emissions for Counties Adjacent to the Lower Snake River

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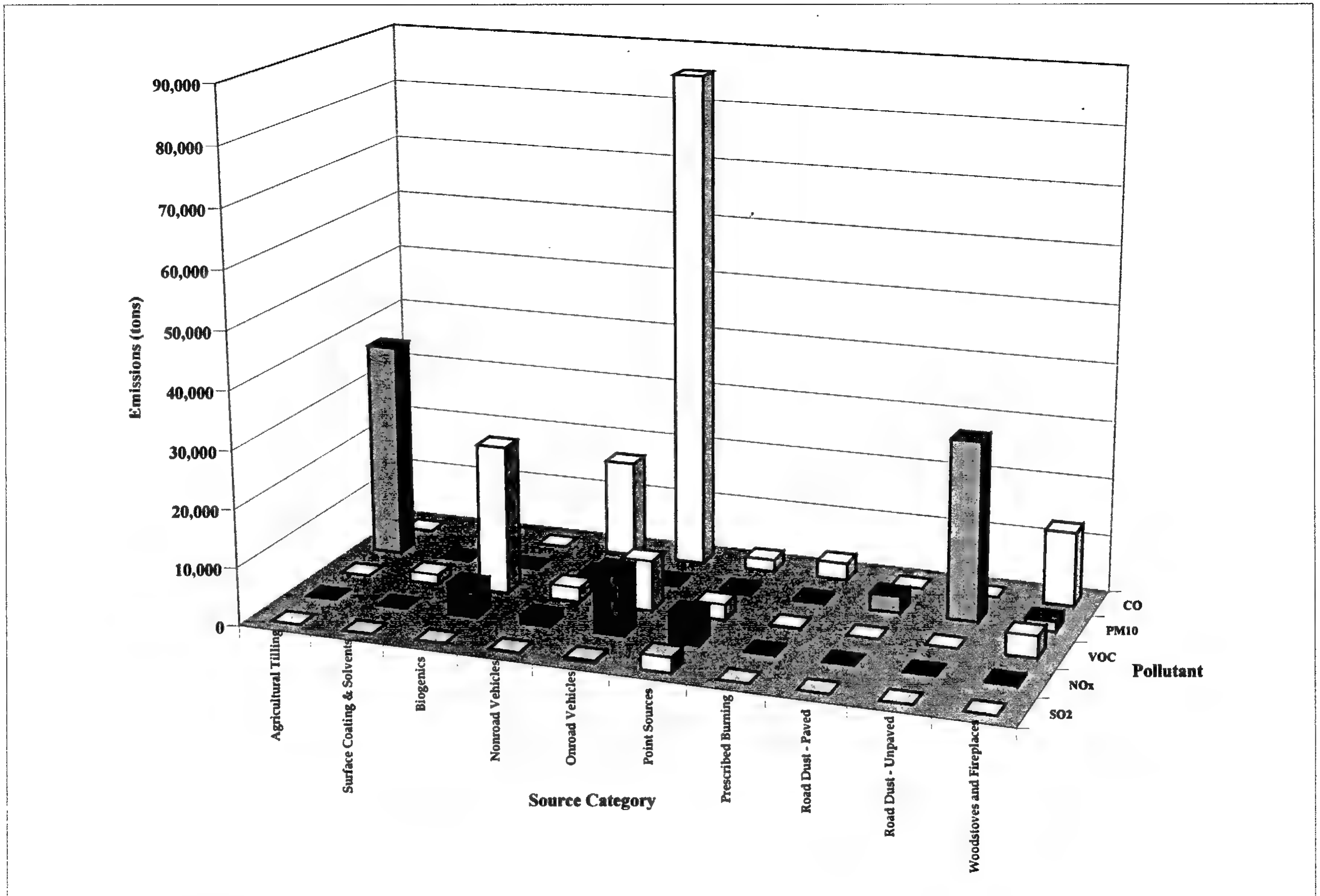

Figure 2-2. Atmospheric Emissions by Source Category for Counties Adjacent to the Lower Snake River

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2.3 Existing Air Quality

2.3.1 Ambient Air Pollutant Concentrations

Although Benton, Franklin, and Whitman counties achieve all state and national AAQS with respect to industrial emissions, windblown fugitive dust continues to be a problem. The second highest 24-hour and annual average PM_{10} concentrations for these counties for the period 1994 through 1999 are presented in Table 2-4. (The second-highest concentrations are used because the AAQS generally allows one exceedance per year of the short-period standards.) Because monitoring stations are located close to major air emissions sources and there are few industrial sources in the areas of the four dams and little agricultural land immediately adjacent to the Snake River, these monitoring data are not representative of air quality at the project locations or at the large agricultural areas subject to wind erosion.

Land use in the area of the lower Snake River is primarily agricultural. From September to November, irrigated and fallow soils are bare and dry, dry harvested fields contain some vegetative residue, and rangelands are dry. Background PM_{10} concentrations during these periods are typically 20 to 40 $\mu g/m^3$. The area is susceptible to erosion during periods of high wind speeds. High wind speeds result in large particulate matter emissions and elevated PM_{10} concentrations along the storm tracks. Monitoring and modeling studies associated with the Columbia Plateau PM_{10} Program (see below) indicate that the largest particulate matter emissions and associated concentrations occur in the area from Kennewick to Spokane and may include the area of the Ice Harbor and Lower Monumental dams.

Table 2-4. Regional Ambient Air Pollutant Concentrations

Station	Station Setting	PM_{10} Concentration ($\mu g/m^3$)	
		Second Highest 24-hour	Annual Average
Kennewick	Residential	103	26.8
Walla Walla #1	Suburban commercial	105	30.7
Walla Walla #2	Agricultural	136	42.1
Clarkston	Industrial	122	37.3
Lewiston #1	Suburban industrial	72	31.3
Lewiston #2	Urban commercial	66	27.4
Spokane #1	Residential	98	34.1
Spokane #2	Commercial	110	31.8
Spokane #3	Residential	103	36.0
Cheney	Wildlife refuge	51	14.9

Source: EPA, 2000b.

Nonattainment areas were discussed in Section 2.1.2. The air quality problem associated with the Wallula nonattainment area appears to be related to industrial emissions and fugitive dust. The other nonattainment areas have problems associated with blowing dust and agricultural practices.

2.3.2 Recent Windblown Dust Studies

Several studies have investigated problems associated with blowing dust. The Northwest Columbia Plateau Wind Erosion Air Quality Project (WEAQP) is a cooperative project that seeks to quantify wind erosion on agricultural lands in eastern Washington. The Great Basin Unified Air Pollution Control District studied wind erosion control methods as part of the Owens Valley, California, PM_{10}

demonstration of attainment. The Lake Koocanusa Fugitive Dust Study measured PM_{10} concentrations associated with seasonal blowing dust from a western Montana lake bed. The results of these studies are summarized below.

2.3.2.1 The Columbia Plateau Wind Erosion Air Quality Project

The Columbia Plateau PM_{10} Program (CP^3) is a multi-investigator study of wind erosion and windblown dust in an area encompassing eastern Washington, northeast Oregon, and the Idaho panhandle, with an emphasis on the role of agricultural lands and regional dust storms. Typical 24-hour background PM_{10} concentrations measured as part of CP^3 are about 34 $\mu g/m^3$ in the early fall and 10 $\mu g/m^3$ in the late fall. During wind events, ambient concentrations at urban receptors can exceed 500 $\mu g/m^3$ on an hourly basis and 300 $\mu g/m^3$ in 24 hours.

The abbreviated objectives of the CP^3 include (WEAQP, 1995):

- Develop a database of climate, soil, vegetation, and farming practices required to estimate PM_{10} emissions.
- Establish the theory, quantification, and verification of wind erosion on agricultural lands, using instrumented field sites and a portable wind tunnel.
- Develop a PM_{10} emissions inventory and probable urban impacts.
- Obtain, test, and evaluate an air transport-dispersion-deposition model suitable to predict PM_{10} concentrations from agricultural emissions sources.
- Identify and test wind erosion and PM_{10} emission control methods and evaluate their effectiveness.
- Reclassify appropriately highly erodible lands for control and develop a strategy to set on-farm compliance and assistance.
- Determine the relative impact of human activity on suspended dust and PM_{10} emission rates by determining erosion rates for non-anthropogenic and anthropogenic areas.
- Develop an awareness and increased understanding about wind erosion, PM_{10} emissions, and current and prospective control methods.
- Increase understanding of the health impacts of particulate air pollution.
- Develop agricultural windblown dust best management practices and implementation policies.
- Develop a particulate air quality plan to achieve solutions to PM_{10} problems throughout the Columbia Plateau.

The most severe windblown dust events occur during the relatively dry September to mid-November period. However, dust storms can also occur during the spring and summer. Dust storms are characterized by a surface low pressure system located in southern British Columbia or Alberta and a surface high pressure system in the southwest United States. The southwest winds generated by the low pressure system are enhanced by the clockwise flow around the high pressure system.

Storms moving through eastern Washington toward the Northeast may affect an area from Kennewick to Spokane, which includes the western area of the lower Snake River. Storms that generate fugitive dust in the western region of the lower Snake River may miss the eastern reach of the river. Other storms may affect the Pendleton to Clarkston/Lewiston area.

The CP^3 program investigated several storms that struck the area between 1990 and 1993. Field measurements during two major dust storms in the fall of 1993 measured maximum 24-hour PM_{10} concentrations equal to 300, 255, and 1,166 of $\mu g/m^3$ at an industrial site in Spokane, a residential site in Spokane, and an urban site in Kennewick, respectively. A regional windblown PM_{10} emissions-dispersion-deposition model was calibrated with data from a portable wind tunnel. The model reasonably reproduced the measured concentrations from the fall of 1993 and was used to predict PM_{10} concentrations throughout the Columbia Plateau (Claiborn et al., 1998).

During the September 11, 1993, windstorm, peak wind speeds were 12.2 meters per second (m/sec) or 27 miles per hour (mph), and measured 24-hour PM_{10} concentrations exceeded 200 $\mu g/m^3$ in Spokane and 100 $\mu g/m^3$ in Kennewick. The highest modeled hourly concentration was over 2,000 $\mu g/m^3$. Total emissions from dry agriculture lands, irrigated agricultural lands, and rangelands for this windstorm are estimated at 116 million metric tons (128 million tons). The emission source was near Kennewick, and the plume stretched to the northeast. During the November 3, 1993, event the winds reached 26 m/sec (58 mph). The highest measured 24-hour concentrations in Adams County reached 187 $\mu g/m^3$, and the highest measured 1-hour concentration in Spokane was 440 $\mu g/m^3$. Total emissions from dry agriculture lands, irrigated agricultural lands, and rangelands are estimated at 81 million metric tons (89 million tons) for this wind event. During both of these events, predicted 24-hour PM_{10} concentrations near the Ice Harbor and Lower Granite reservoirs were 2,400 and 50 $\mu g/m^3$, respectively.

The studies conducted by CP^3 are directly related to the problem of windblown dust and the impacts of dam removal. CP^3 modeled several storms without the dry lower Snake River reservoirs as emission sources and recently re-ran the models including the dry reservoirs as sources, thereby helping to define impacts associated with dam breaching. As an original sponsor of the CP^3 project, Ecology has received the results of the original studies. Through its public awareness and research programs, CP^3 has helped increase understanding of the nature of dust-related problems in eastern Washington and has developed guidance to assist the agricultural industry in its efforts to reduce fugitive dust emissions.

2.3.2.2 The Owens Valley PM_{10} Demonstration of Attainment

The Owens Valley PM_{10} Demonstration of Attainment provided information relevant to the impacts associated with drawdown. Owens Lake, located in eastern central California, is the source of large amounts of dust. The southern portion of the Owens Valley is a "serious" PM_{10} nonattainment area. The designation is "serious" because of frequent violations of the national AAQS and the inability of the area to attain the standards by December 31, 1995. Emissions from Owens Lake have been predicted to cause exceedances of the 24-hour AAQS up to 31 km (50 miles) away. The Great Basin Unified Air Pollution Control District published an attainment plan in 1998, which includes ambient meteorological and PM_{10} measurements, dust emission measurements, and the effectiveness of several control strategies.

Winds exceeding 18 m/sec (40 mph) are associated with passing storm systems. When storm systems approach the Owens Valley, strong southerly winds switch to strong northerly winds with passage of the front. Data from a monitoring network indicate that PM_{10} concentrations in communities adjacent to or near the dry lake frequently exceed the AAQS. The peak 24-hour concentrations and the expected number of exceedances per year, derived from about 9 years of sampling, are shown in Table 2-5.

Table 2-5. Peak 24-hour Concentrations and the Expected Number of Exceedances Per Year near Owens Lake, California

Location	Direction from Owens Lake	Peak 24-hour PM_{10} Concentration ($\mu g/m^3$)	24-Hour Average Wind Speed (m/sec)	Date of Peak Concentration	Expected Number of Exceedances Per Year
Keeler	East	3,929	14.6	4/13/1995	19
Lone Pine	North	499	10.7	3/18/1994	2
Olancha	South	2,252	13.0	4/9/1995	5

Source: Great Basin Unified Air Pollution Control District, 1998.

Owens Lake and secondary sources (windborne deposits of Owens Lake material) comprise 99.99 percent of the PM_{10} emissions inventory of Inyo County. Wind tunnel measurements, sun photometry (measuring changes in scattered sunlight), and field mapping of eroded areas were used to estimate annual PM_{10} emissions of between 118,000 and 382,000 MTY (130,000 and 420,000 TPY). Owens Lake dust also contains arsenic and cadmium at concentrations that result in lifetime cancer risks of 18 per million and 6 per million, respectively. The cancer risk values are based on the 9-year average PM_{10} concentration of 50 $\mu g/m^3$.

Several emission control strategies have been tested at Owens Lake. The testing included estimating their effectiveness at reducing PM_{10} emissions. The proposed control strategies are shown in Table 2-6.

Table 2-6. Effectiveness of Owens Lake Fugitive Dust Emission Control Strategies

Control Method	Emissions Reduction (Percent)	Coverage
Shallow flooding	99	75 percent of emitting area between September and June
Managed vegetation	99	50 percent plant coverage on 75 percent of the managed area
Gravel cover	100	100 percent

Source: Great Basin Unified Air Pollution Control District, 1998.

Shallow flooding will mimic the physical and chemical processes of natural springs and wetlands on the relatively flat Owens Lake playa. Winter and spring flooding are effective in reducing emissions because summer wind events are rare. The salt-affected soils of Owens Lake must first be reclaimed before salt-tolerant plants, such as saltgrass, can be planted. The gravel cover consists of a 101.6-millimeter (mm) (4-inch) layer of gravel greater than 9.5 mm (3/8 inch) in diameter. The gravel cover increases the threshold velocity required to move surface particles. To remain effective, the gravel cover must not become covered with dust.

The control strategies proposed for Owens Lake have been adopted in this appendix as demonstrated and achievable methods of reducing emissions from dry lake sediments. The Great Basin Unified Air Pollution Control District's effort to understand and address the Owens Lake fugitive dust problem is a model for the effort that will be required in eastern Washington if the region is designated as a PM_{10} nonattainment area.

2.3.2.3 The Lake Koocanusa Fugitive Dust Study

A recent similar study has illuminated the meteorological conditions associated with high fugitive dust events (Environalysis, 1996). PM_{10} monitoring was conducted at Lake Koocanusa, the reservoir formed by Libby Dam on the Kootenai River in northwestern Montana. Lake Koocanusa refills with snowpack melt in the late spring and summer. Two years of monitoring (May 1994 through June 1996) measured meteorological conditions, continuous PM_{10} concentrations at the lake and in the nearby town of Eureka, and passive dust settling measurements. The following meteorological conditions are associated with entrainment of fugitive dust:

- High dust events are preceded by several hours of increasing wind speeds from a constant direction.
- The wind speeds that initiate a dust event are not unusually high. A minimum threshold of wind energy is required to initiate the dust event.
- The high wind events last up to 9 hours.
- Background dust levels may significantly contribute to the measured concentrations.
- Dust levels rapidly fall when the wind speed drops below about 5 m/sec (10 mph).
- Dry lake banks appear to provide turbulent conditions that enhance emissions and produce more emissions.

The geography and microtopography of the dry lakebed sediments can be an important factor. Different wind patterns can affect different areas of the lakebed. Steep slopes, which allow heavier particles to roll downslope, make smaller particles available for entrainment. Although some 1-hour PM_{10} concentrations measured during the Lake Koocanusa study were very large, all 24-hour concentrations were lower than the air quality standard.

On several occasions, measured maximum 1-hour PM_{10} concentrations exceeded about 500 $\mu g/m^3$. In all cases, the average 24-hour PM_{10} concentrations were below 100 $\mu g/m^3$, or about 67 percent of the AAQS. The dust events were characterized by moderate persistent winds and dry conditions and lasted from between 3 and 9 hours. The largest measured 1-hour concentration was associated with winds that blew over large areas of exposed lake banks.

2.4 Climatic Factors

Dry, loose lake sediments become airborne during high wind events. Surface particles are much less mobile if the ground is wet or frozen. The greatest potential for windblown dust coincides with periods of low relative humidity, extended sunshine, and warm to hot temperatures. The wind, precipitation, and temperature conditions of the lower Snake River region are discussed below. Monthly tabulations of climatic variables are presented in Annex A.

2.4.1 Precipitation and Temperature

The availability of soils that may be subject to wind erosion is partially a function of the precipitation and temperature climatology of the region. Moisture helps hold soil particles together and reduces erosion potential. Higher temperatures enhance evaporation, drying soils and providing particulate matter that may be subject to wind erosion. Soil erosion is negligible when the temperatures are below freezing.

The Cascade Mountains effectively block most precipitation from entering southeast Washington and northeast Oregon. Annual precipitation amounts are about 250 mm (10 inches) or less, with most of the precipitation falling during the winter (Figure 2-3) (Corps, 1999). Some locations in southeast Washington and northeast Oregon experience only small amounts of summer rain. Relative humidity values can fall to 10 percent or less on hot summer afternoons. Precipitation amounts generally increase with elevation and are slightly higher in the Clarkston and Lewiston area.

Climatic conditions in the lower Snake River area are characterized by large seasonal temperature differences, low precipitation, and relatively minimal cloud cover. Valley bottoms along the Snake River have the highest summer temperatures in the region, and they tend to stay slightly warmer than surrounding upland areas in the winter.

Precipitation is typically concentrated in the late fall, winter, and early spring, with more arid conditions prevailing from late spring through the summer. Precipitation reduces the availability of particulate matter susceptible to erosion during high wind speed conditions. The reservoirs on the middle and lower Snake River generally experience measurable precipitation on 90 to 120 days per year (Jackson and Kimerling, 1993).

Long-term precipitation and temperature data are available for Ice Harbor Dam, which is representative of the western Snake River area. Precipitation and temperature data from Lewiston, located about 40 km (25 miles) southeast of the Lower Granite Dam, are representative of the eastern area of the lower Snake River. In general, normal precipitation amounts increase and temperatures decrease from west to east across the lower Snake River area (Figures 2-3 and 2-4). Figures 2-3 and 2-4 are based on more than 30 years of data (NOAA, 1999 a and b).

2.4.2 Wind Conditions

Air quality at specific locations within the basin is heavily influenced by wind conditions, which in turn reflect both prevailing regional patterns and local topographic factors. The prevailing wind direction in southeastern Washington is from the southwest in both winter and summer. Average wind speeds throughout the basin are generally in the range of 11 to 13 kilometers per hour (km/hour) (7 to 8 mph). Some locations have considerably higher wind speeds (Jackson and Kimerling, 1993).

Infrequent July and August thunderstorms, which usually drop only small amounts of rain, are sometimes accompanied by strong wind gusts. Winter weather conditions in the region often produce strong winds flowing across the region. Local winds in the reservoir areas are often channeled parallel to the shoreline by the river valleys. Local topography can also act as a funnel that increases wind speeds. A daily cycle of changing up-valley and down-valley local wind directions can be common, particularly in mountain areas.

Ice Harbor wind data for the period August 1999 through October 2000 have been provided by the Corps. The data indicate that the winds generally follow the orientation of the river. During the winter and spring, the winds are primarily from the southwest through the west. The early summer westerly winds shift to easterly winds during the late summer and early fall. During the late fall, the winds are again from the south southwest. Winds with low nighttime speeds are often from the east.

Long-term wind speed and wind direction data are available from only a limited number of stations, all of which are located outside the lower Snake River area. The three closest stations are Pendleton, Oregon, and Spokane and Yakima, Washington.

Annual wind distributions are presented in Figures 2-6 through 2-9 as windrose figures for the Ice Harbor, Pendleton, Spokane, and Yakima monitoring stations, respectively. A windrose figure depicts the joint frequency of occurrence, in percentage, of wind speed and wind direction categories for a particular location and time period. The radials of the windrose indicate the direction from which the wind is blowing. The length of the radials indicates the frequency of occurrence for that direction, and the width of the radials indicates the wind speed class. The Pendleton, Spokane, and Yakima windrose figures are for the 8-year period between 1984 and 1991, and the Ice Harbor windrose figure is for the period August 1999 to October 2000.

Table 2-7 lists primary wind directions, average wind speeds, and peak gusts for selected local meteorological monitoring stations. These average and peak gust speeds are relatively high, leading to a significant potential for windblown dust if soil or sediments are exposed. Much of the interior plateau area near the Columbia and Snake rivers is dominated by fine-grained loessal soils that are particularly susceptible to wind erosion (Jackson and Kimerling, 1993).

Dry lake sediments are subject to erosion when the 1-hour average wind speeds reach 7.5 m/sec (16.7 mph) and the ground is not wet or frozen. Larger emissions are expected with higher sustained speeds. The data used to generate the windrose figures were scanned to determine how often high wind speeds may be expected. The percent of time when 1-hour average wind speeds are greater than 7 and 10 m/sec for four monitoring stations is as follows:

Percent of Hours Winds Are Greater than	Ice Harbor	Pendleton	Spokane	Yakima
7 m/sec (15.7 mph)	13	6	13	7
10 m/sec (22.4 mph)	3	1	2	1

Dust storms in eastern Washington are most common from September through November (Claiborn et al., 1998). The meteorological data indicate that, on average, there are about 10 high-wind-speed events of varying intensity per year from September through November.

Air quality concerns regarding industrial emission sources such as power plants pertain to different meteorological conditions. Maximum air pollutant concentrations resulting from stacks and combustion sources are a consequence of low wind speeds and very stable atmospheric conditions. Once a plume is emitted from a stack, the final height is a function of the effects of momentum and buoyancy. Greater plume rise is usually achieved with colder ambient temperatures.

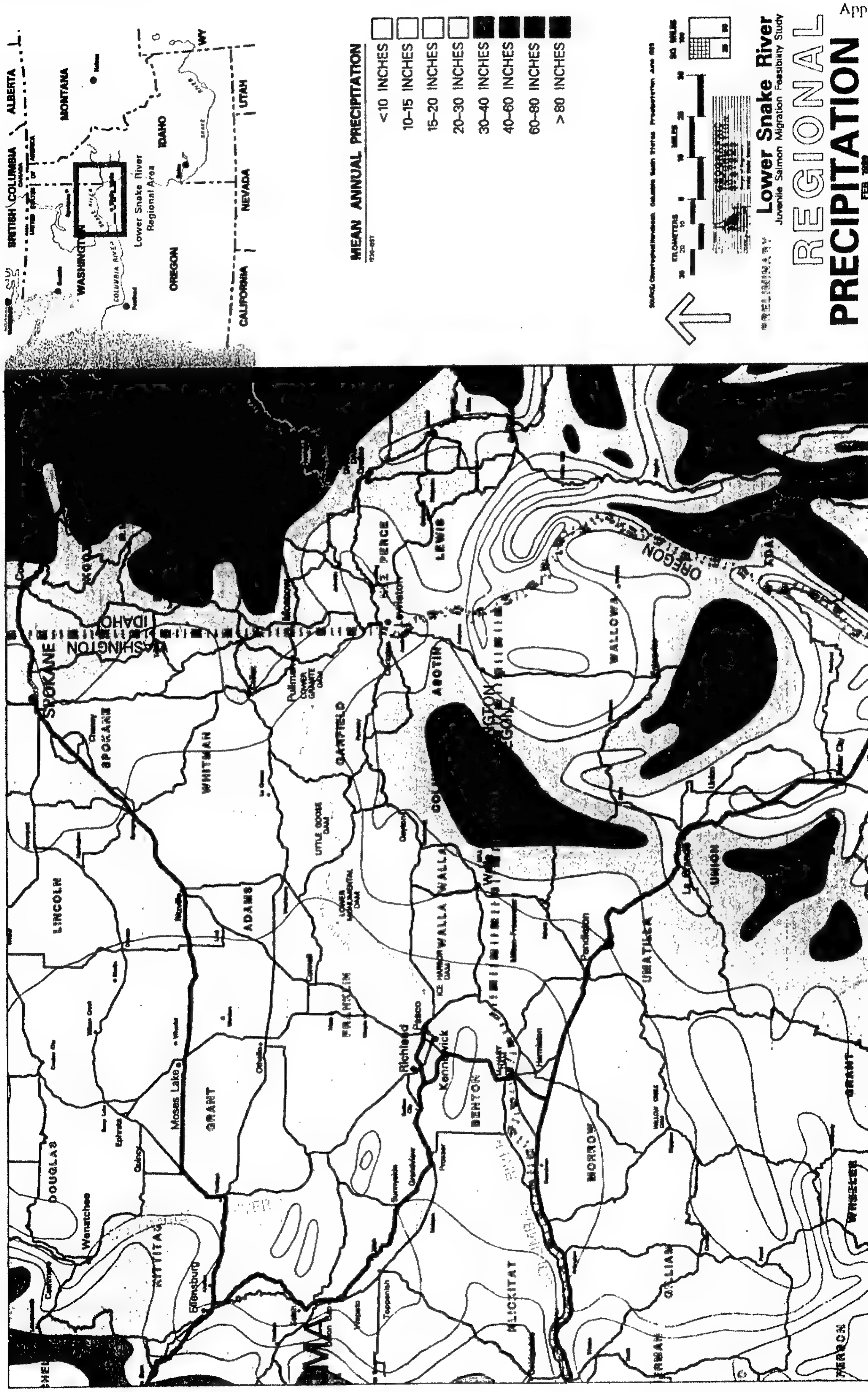

Figure 2-3. Regional Precipitation

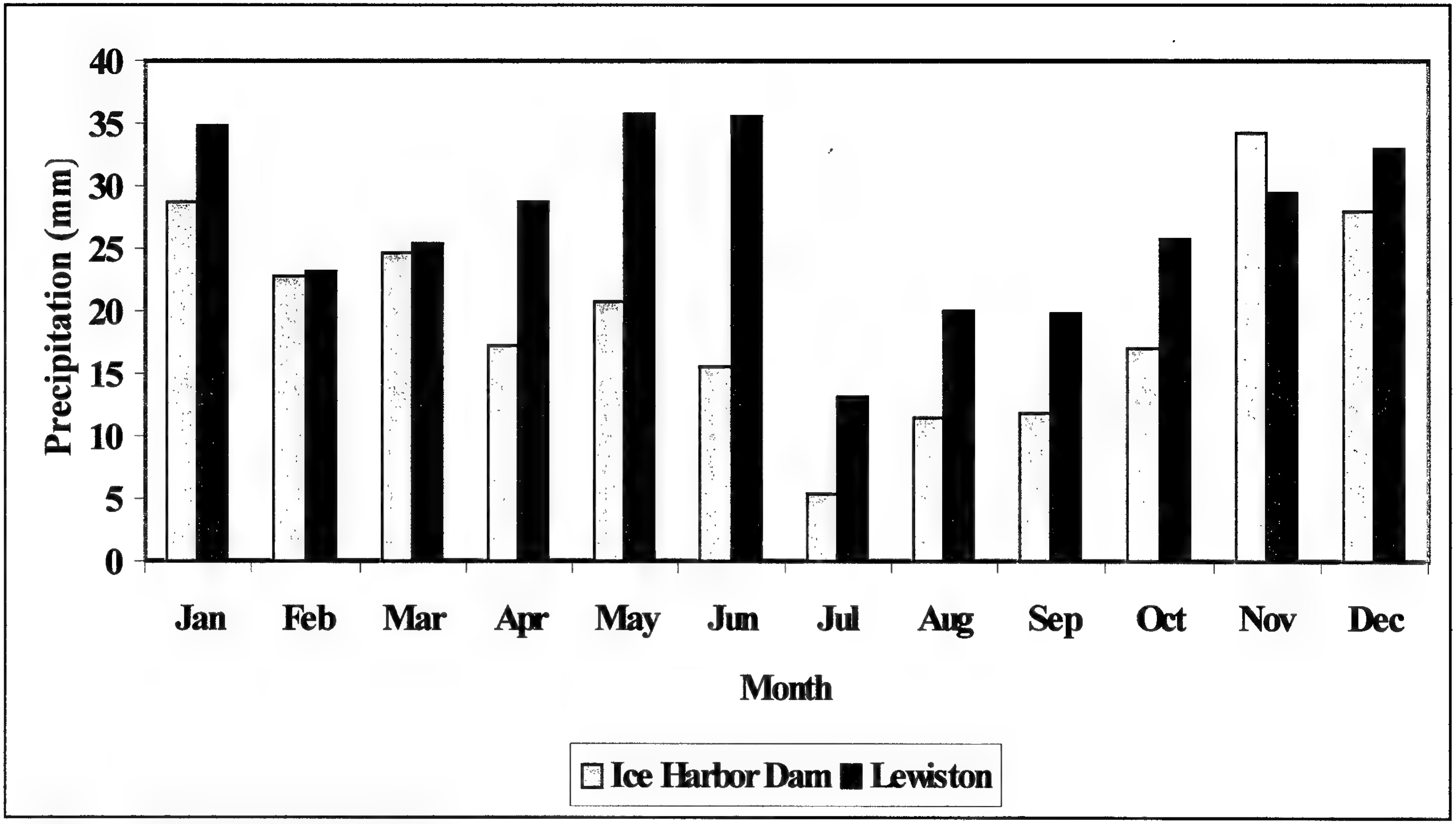

Figure 2-4. Average Monthly Precipitation Totals

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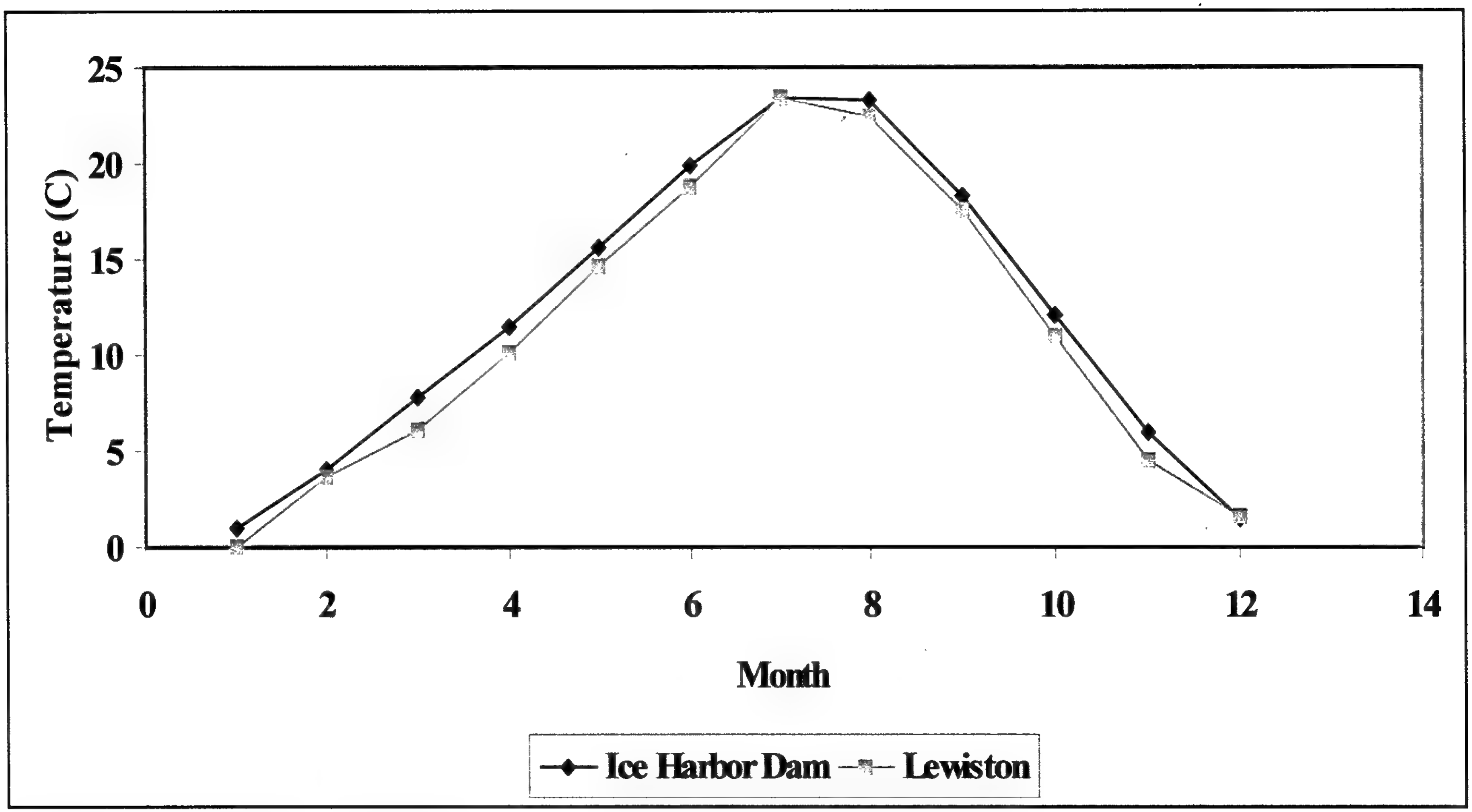

Figure 2-5. Average Monthly Temperatures

Table 2-7. Wind Directions and Speeds for Selected Monitoring Stations

Variable		Location			
		Ice Harbor	**Pendleton**	**Spokane**	**Yakima**
Average	Direction (deg)	W	W	SW	W
	Speed (m/sec)	3.5	3.7	3.9	3.2
	Speed (mph)	7.8	8.3	8.8	7.1
Peak Gust	Direction (deg)	NNW	SW	SW	NE
	Speed (m/sec)	24.9	34.0	27.7	30.8
	Speed (mph)	56	76	62	69
Fastest Mile	Direction (deg)	-	W	SW	W
	Speed (m/sec)	-	34.4	26.4	21.5
	Speed (mph)		77	59	48

Source: NOAA, 1990a, b, c; 1997a, b, c.

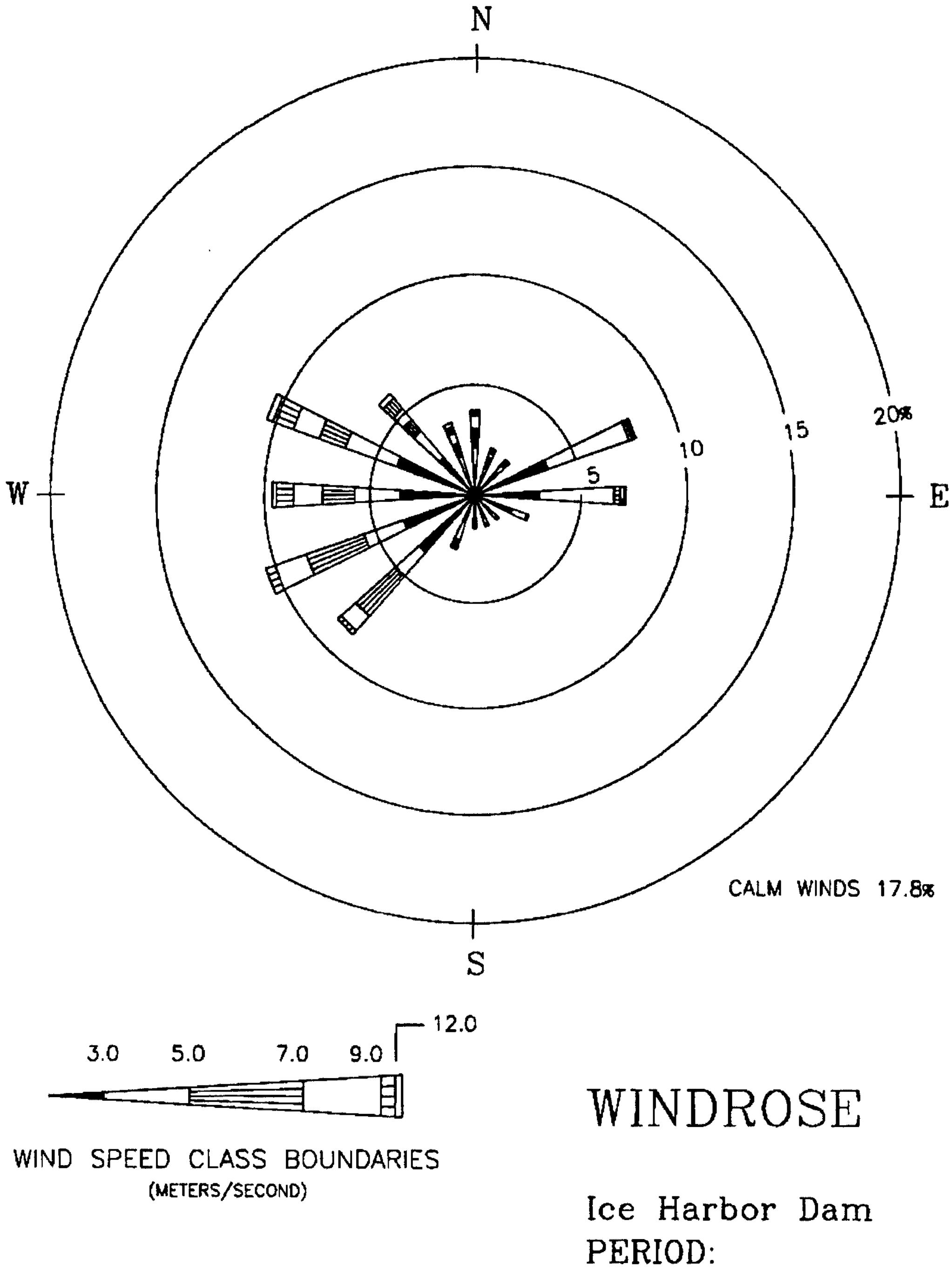

Figure 2-6. Ice Harbor, Washington Windrose for August 1999–October 2000

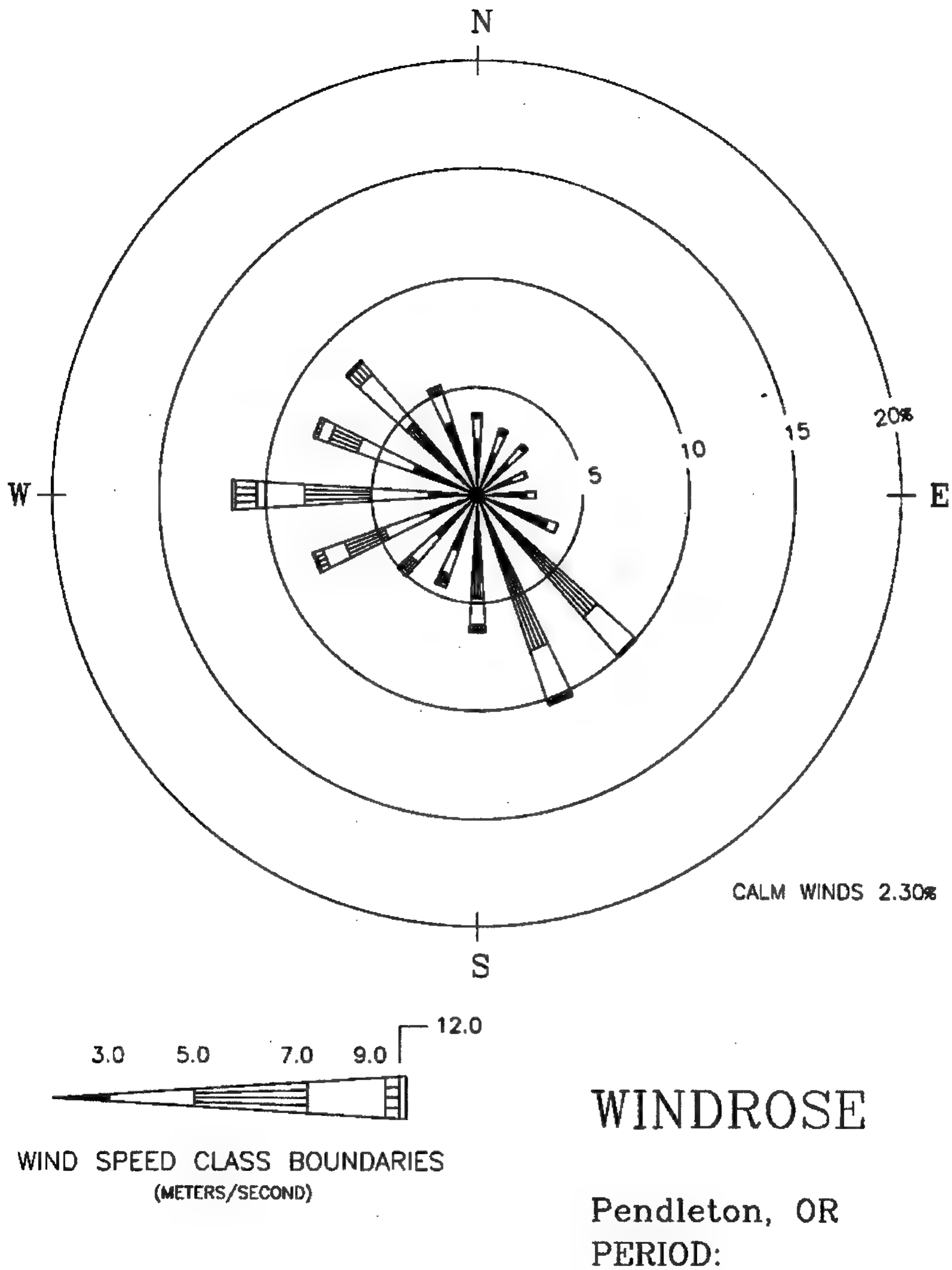

Figure 2-7. Pendleton, Oregon Windrose for 1984–1991

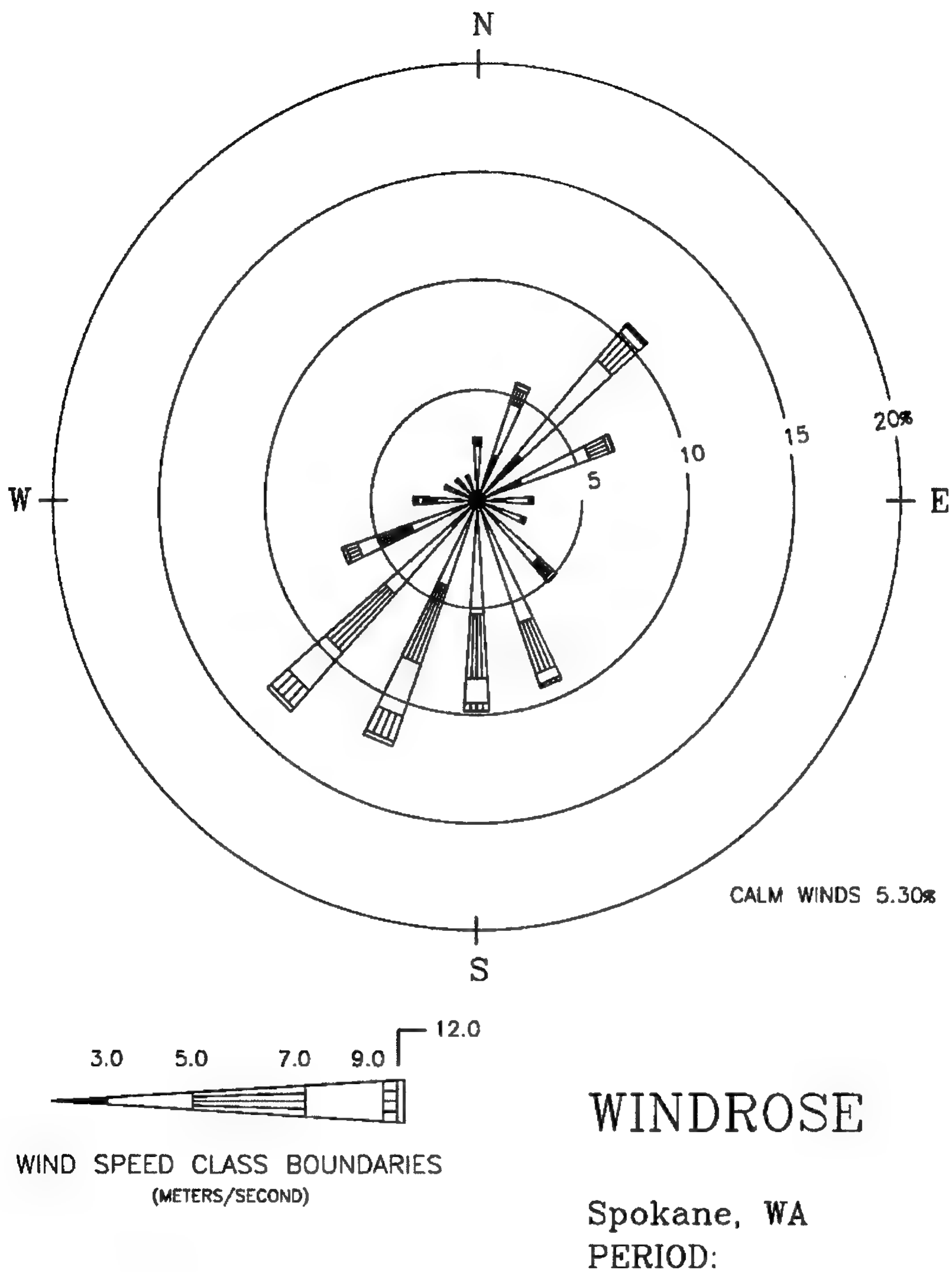

Figure 2-8. Spokane, Washington Windrose for 1984–1991

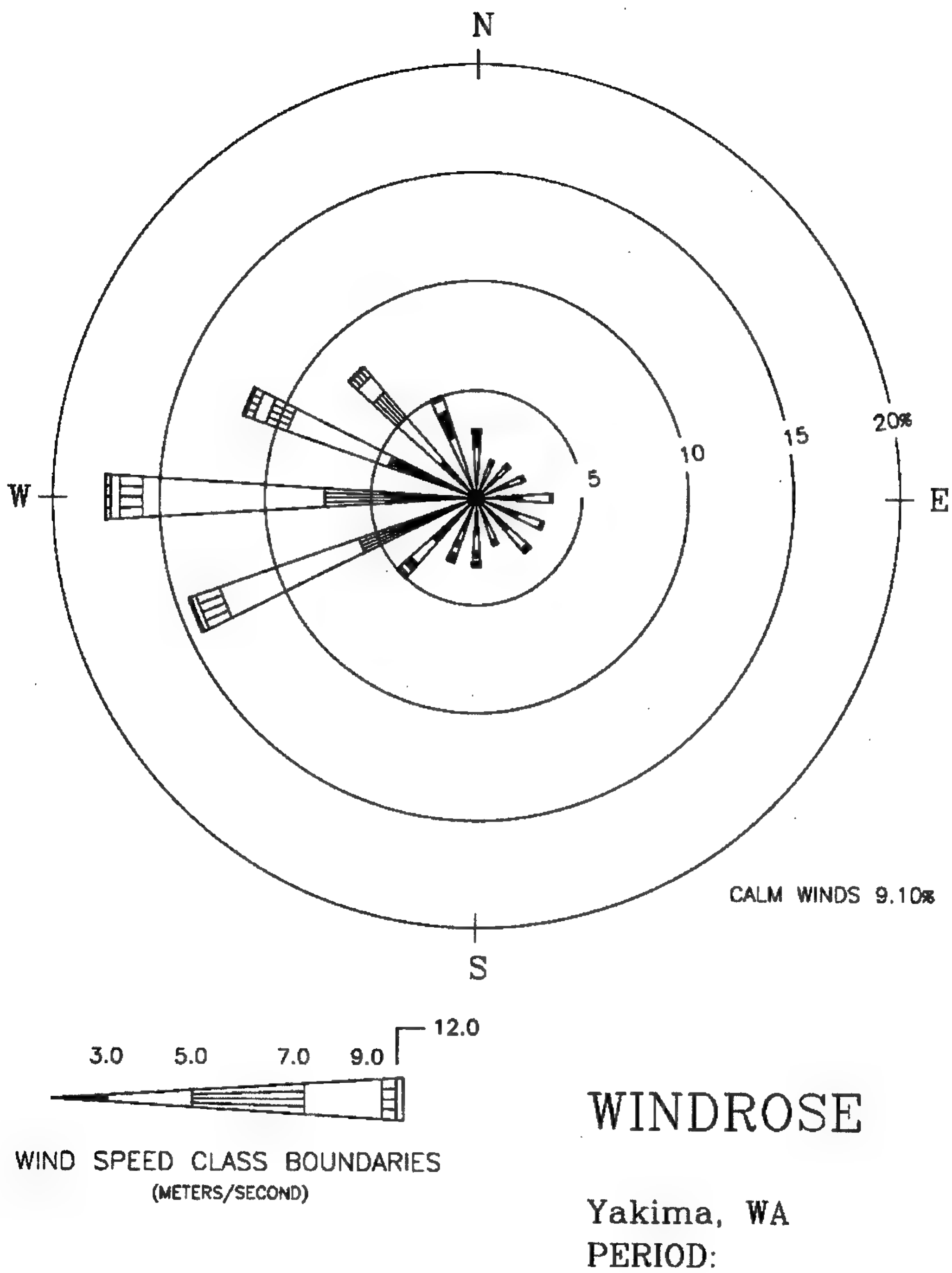

Figure 2-9. Yakima, Washington Windrose for 1984–1991

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3. Study Methods

Section 3 presents the methods used in this analysis of the air quality impacts associated with the Feasibility Study alternatives. This analysis addresses the four impact issues identified in Section 1:

- Fugitive dust emissions resulting from demolition of the dams
- The change in transportation-related emissions
- Effects of fugitive dust
- Emissions associated with replacing lost hydropower.

Under the Dam Breaching alternative, the lower Snake River dams would be breached. Demolition activities such as hauling and dumping fill material would generate fugitive emissions. Section 3.1 presents methods used to estimate construction-related fugitive emissions.

Between 2.7 million and 3.6 million metric tons (3 and 4 million tons) of freight pass through Ice Harbor Dam every year. Towboats emit pollutants along the length of the river from the confluence of the Columbia and Snake rivers to Lewiston, Idaho. The Dam Breaching alternative would require a transfer of river freight to rails and roads, changing the amount and distribution of traffic-related air emissions. Section 3.2 presents the methods used to estimate the change in transportation-related emissions.

Wind-generated dust originating from dry reservoir sediments could be a problem in areas adjacent to the reservoirs. Limited monitoring data are available to characterize emissions from dry lake beds. As an alternative, a method for predicting the amount of particulate matter (PM_{10}) emitted during high wind speed events is presented (Section 3.3).

The Dam Breaching alternative would require replacement of hydropower through increased power generation from existing plants or construction of new power-generating capacity. Replacement of hydropower would increase atmospheric emissions of criteria air pollutants, HAPs, and GHGs. Section 3.4 presents the methods used to estimate emissions associated with replacement hydropower.

3.1 Demolition Fugitive Emissions

In terms of atmospheric emissions, excavation and deconstruction of the lower Snake River dams would be equivalent to a large construction project. According to the Natural River Drawdown Engineering Appendix (Appendix D), demolition will be conducted in 2 years. However, deconstruction could last longer, depending on the project schedule and whether one or more dams are demolished simultaneously. This analysis conservatively assumes that all four projects are demolished in 1 year. In addition, emissions associated with rock quarried for embankment repairs, drainage structure protection, and level fill are included.

The principal construction operations that generate fugitive dust include unloading material from trucks and hauling, bulldozing, and grading the material. Construction activities are generalized into bulldozing, batch dropping, hauling on unpaved roads, and grading. The analysis estimates fugitive dust emissions and the resulting ambient concentrations.

3.1.1 Emission Calculations

Emissions have been estimated for embankment and abutment excavations and construction and diversion levees. In addition, emissions associated with quarry excavation for levee stabilization have been estimated.

3.1.1.1 Embankment and Abutment Excavation Emission Estimates

Equations for estimating construction-related emissions are available from EPA (1998). The emission factor equations are based on material handling rates, soil moisture content, silt content, and other factors such as vehicle weight and wind speed. The expressions include dimensionless multipliers to account for aerodynamic particle size. For this study, multipliers for PM_{10} have been incorporated into the equations. The equations also include the mitigating effects of rain. The emission factor expressions used in this study are presented in Table 3-1. Bulldozer emissions are expressed in units of kilograms per hour (kg/hour). Hauling and grading emission factors are expressed in terms of vehicle kilometers traveled (VKT). Dropping emission factors are in terms of the amount of material in metric tons (MT).

Table 3-1. Fugitive Dust Emission Equations

Operation	EPA, 1998 Reference	Units	Equation
Bulldozing	Table 11.9-2	kg/hour	$EF_B = 0.75 * (0.45 * (s^{1.5}/M^{1.4}) * (365\text{-}p)/365$
Hauling	Section 13.2.2	g/VKT	$EF_H = 281.9 * (2.6 * (s/12)^{0.8}(W/3)^{0.4}) / (M/0.2)^{0.3} * (365\text{-}p)/365$
Dropping	Section 13.2.4	kg/MT	$EF_D = 0.35 * 0.0016 * (u/2.2)^{1.3} / (M/2)^{1.4} * (365\text{-}p)/365$
Grading	Table 11.9-2	kg/VKT	$EF_G = 0.60 * 0.0056 * S^{2.0} * (365\text{-}p)/365$
Where:	M = moisture content, in percent		
	p = number of days with measurable precipitation		
	s = silt content, in percent		
	S = mean vehicle speed, in km/hour		
	u = mean wind speed, in m/sec		
	W = mean vehicle weight, in metric tons.		
Source: EPA, 1998.			

Annual fugitive emissions of PM_{10} are estimated for bulldozing, loading, hauling, dumping, and grading operations for each project, based on the amount of soil and fill material that must be moved to breach the dams. The emission calculations require volume of material, road lengths, and average weight of the haul trucks. The analysis does not include vehicle tailpipe emissions or emissions from worker camps. The default values for constants used in the emission calculations are presented in Table 3-2.

Table 3-2. Default Values for Emission Calculations

Constant	Symbol	Metric Value	Metric Unit	English Value	English Unit	Reference
Constants Used in Excavation Calculations						
Average grader speed	S	11	kph	7	mph	EPA, 1998
Average trip length		3.2	km	2.0	miles	Appendix D
Average truck speed		24.1	kph	15.0	mph	EPA, 1998
Moisture content	M	8	percent	8	percent	EPA, 1998
Silt content	S	7	percent	7	percent	EPA, 1998
Weight of fill material		1.48	MT/m^3	1.25	ton/yd^3	
Constants Used in Quarry Emission Calculations						
Rock moisture content	M	2.1	percent	2.1	percent	EPA, 1998
Road moisture content	M	0.2	percent	0.2	percent	EPA, 1998
Rock silt content	S	3.9	percent	3.9	percent	EPA, 1998
Road silt content	S	8.3	percent	8.3	percent	EPA, 1998
Average trip duration		0.75	hours	0.75	hours	
Average trip length		12.9	km	8	miles	
Weight of fill material		1.22	MT/m^3	1.755	ton/yd^3	
Constants Used in All Emission Calculations						
Days with rain	p	91.4	days	91.4	days	NOAA, 1997a,b,c
Control efficiency		50	percent	50	percent	EPA, 1998
Project duration		1	year	1	year	Appendix D
Average wind speed	u	3.6	m/sec	8.1	mph	NOAA, 1997a,b,c

The Natural River Drawdown Engineering Appendix (Appendix D) provides conceptual designs for breaching the four lower Snake River dams, channelizing the river, and modifying the reservoirs. In Appendix D, the Dam Embankment Excavation Plan (Annex B) presents an estimate of the volume of fill material that would be removed from each site. The River Channelization Plan calls for construction of diversion levees at each site to direct river flow into and through new channels and around concrete structures. Between 400,000 and 900,000 cubic yards (yd^3) of material are required for the levees at each site. The volume of material excavated and the quantity of material needed for the levees are presented in Table 3-3.

When excavated, the core material will be saturated with water and will not be a source of particulate matter emissions. However, this material is a small percentage of the total volume of material to be excavated and was included in the analysis. The material excavation rates typically range from about 920 to 1,920 m^3/hour (1,200 to 2,500 yd^3/hour). Two truck types, 35 and 85 tons, will haul the material to stockpiles about 3 km (2 miles) from the site. Haul road emissions are based on the volume of material excavated, the number of trips, and the length of each round trip. The emission calculations assume that good construction practices will be followed to minimize road dust. This analysis assumes that construction practices will reduce haul road fugitive dust emissions by 50 percent (EPA, 1998).

Table 3-3. Excavation Quantities

Material	Excavation Volume (m^3) Ice Harbor	Lower Monumental	Little Goose	Lower Granite
Embankment				
Core material	7,500	78,300	138,300	240,200
Gravel fill	59,500	675,200	978,000	1,101,700
Cofferdams			263,900	276,400
Common Excavation				
Abutments	3,971,000	4,395,500		
Temporary cofferdams	228,480	172,340		
Diversion Levees				
Levee fill	415,308	395,000	689,000	326,000
Total	**4,681,788**	**5,716,340**	**2,069,200**	**1,944,300**

Sources: Table B1 in Annex B (Dam Embankment Excavation Plan) to Appendix D (Natural River Drawdown Engineering).
Table D1 (River Channelization Plan) in Appendix D (Natural River Drawdown Engineering).

Emissions generated by the batch dropping of truckloads are estimated from the volume of material excavated. Bulldozer and grader emissions are based on the number of hours of operation estimated for this equipment (Table 3-4).

Table 3-4. Deconstruction Engineering Data

	Ice Harbor	Lower Monumental	Little Goose	Lower Granite
Bulldozer hours	50,359	37,177	34,048	44,345
Total material volume (m^3)	258,139	944,639	1,571,339	1,809,439
Batch drop volume (m^3)	258,139	944,639	1,571,339	1,809,439
Grader hours	50,359	37,177	34,048	44,345

Source: Appendix D, Natural River Drawdown Engineering.

The Natural River Drawdown Engineering Appendix (Appendix D) includes a number of plans for reservoir modifications, including bridge modifications, reservoir embankment protection, treatment of drainage structures, railroad and roadway repair, and modification of recreation sites. Construction details sufficient for emission estimates have not been specified. Reservoir modifications may include, but are not limited to, placement of fill material, rip-rap, rock, and concrete, as well as excavations of fill material. Construction activities may include use of haul roads and heavy equipment such as bulldozers and graders. The location and schedule of these activities, types of material to be placed or removed, and volume of material involved have not been specified. Therefore, emissions associated with reservoir modifications have not been included in this analysis.

Structural enhancements to improve the downstream migration of juvenile salmon would be added to each of the lower Snake River facilities under the Major System Improvements alternative. Most of these enhancements are surface bypass and collection (SBC) systems. Details of the enhancements are presented in the Existing Systems and Major System Improvements Engineering Appendix (Appendix E).

The SBC structures would be built in place or would be built offsite and assembled onsite. Assuming that onsite construction would be employed, the emission sources for the Major System Improvements alternative include construction-related activities such as cement mixing and unpaved road emissions. Small emissions would result from loading cement, sand, aggregate, and water into mixer trucks. Particulate matter, primarily cement dust from the mixer trucks, is the pollutant of concern. EPA emission factors for truck-mixed concrete are 0.01 kg/MT of cement (0.04 lb/yd^3) (EPA, 1998, Table 11.12-2 dated 10/86).

Construction-related emissions for the Major System Improvements alternative would be very small. To provide emission quantities for a comparison of the alternatives, construction-related emissions have been assumed to equal 1 MTY (1 TPY) for all four hydrofacilities. While unknown at this time, it is possible that modifications in farming patterns due to regional economic changes (such as shifts from irrigated to dryland farming) could also lead to changes in emissions.

3.1.1.2 Quarry Excavation Emission Estimates

The quarries will be used until all rock necessary for embankment repairs, drainage structure protection, and levee fill is obtained. This analysis assumes that all quarries will operate for one full year. The principal operations that generate fugitive dust are crushing and screening material, loading and unloading material on trucks, and hauling on unpaved roads.

Equations for construction-related emission factors as well as crushed stone processing are available from EPA (1998). The emission factor equations are based on material handling rates, soil moisture content, silt content, and other factors, such as vehicle weight and wind speed. The expressions include dimensionless multipliers to account for aerodynamic particle size. For this study, multipliers for PM_{10} have been incorporated into the equations. The equations also include the mitigating effects of rain. The emission factor expressions used in this study are the same as those presented in Table 3-1.

Annual fugitive emissions of PM_{10} are estimated for screening and crushing rock, and loading, hauling, and dumping operations for each quarry, based on the amount of rock that must be processed at each quarry. The emission calculations require volume of material, road lengths, and average weight of the haul trucks. The calculations also include hauling and dumping during final placement of the material. The analysis does not include vehicle tailpipe emissions or emissions from worker camps. The default values for constants used in the emission calculations are presented in Table 3-2.

The Natural River Drawdown Engineering Appendix (Appendix D) provides conceptual designs for breaching the four lower Snake River dams, river channelization, and reservoir modifications. Annex D to Appendix D, the River Channelization Plan, provides an estimate of the volume of levee fill material required. Annex F, the Railroad and Highway Embankment Protection Plan, presents an estimate of the volume of fill material required for embankment modification. Annex G, the Drainage Structures Protection Plan, provides information regarding the amount of material required for drainage structure protection. Annex H, the Railroad and Roadway Damage Repair Plan, presents an estimate of the amount of fill needed for road and railroad embankment repairs. The total volume of material needed from each quarry is presented in Table 3-5. Quarry excavations will take place over a period of 3 years. However, to be consistent and comparable with the other emission estimates, this estimate assumes that the excavations will be completed in 1 year. This is

Table 3-5. Quarry Excavation Quantities

Quarry and River Mile Destination	Excavation Quantities (m^3) Quarry 1 (RM20) Ice Harbor Area	Quarry 2 (RM60) Lower Monumental and Little Goose Areas	Quarry 3 (RM133) Lower Granite Area
Levee fill material	326,000	1,084,000	415,308
Reservoir embankment modification	200,566	411,664	288,823
Road/railroad repairs	156,682	418,336	362,090
Drainage structures	2,900	5,304	4,427
Total	**686,149**	**1,919,306**	**1,070,651**

also done to try and understand how extensive the effects might be if quarrying was, for some reason, done in a 1-year period. This approach is consistent with EPA screening procedures (see Section 3.1.2).

The amount of fill material excavated from the quarries will be about 2 to 3 times greater than the amount of material needed. For this analysis, it was assumed that the volume of material processed is 3 times greater than the volume of material needed. Two truck types, 35T and 85T, will haul the material about 13 km (8 miles) to barges at the river (the exact distances of the quarries from the river have not been specified). Haul road emissions assume that the roads are unpaved and are based on the volume of material quarried, the number of trips, and the length of each round trip. The emission calculations assume that good construction practices will be followed to minimize road dust. This emission estimate assumes that construction practices will reduce haul road fugitive dust emissions by 50 percent.

Emissions generated by screening and crushing quarried material are based on EPA emission factors and the volume of material processed. Emissions generated by the batch dropping of truckloads are estimated from the volume of material required from each quarry.

Quarried material will be stockpiled in several locations along the river before being hauled to its final placement location. Primary sources of emissions are hauling and dumping of the material. The number of trips necessary for final placement of the material has been estimated in this analysis.

3.1.2 Construction Fugitive Dust Modeling

The largest quantity of excavation materials and thus the largest amount of PM_{10} emissions are associated with demolition of the Lower Monumental Dam and excavations at Quarry 2, located near river mile (RM) 60 (Tables 3-3 and 3-5). The haul roads are the largest single source of emissions. To obtain a rough estimate of ambient concentrations associated with the excavations, PM_{10} emissions from haul road segments and the stockpiles were modeled. Portions of an existing road near the Lower Monumental Dam were modeled. A hypothetical haul road from Quarry 2 to the river was also modeled. Because it is not known where public access will be restricted during demolition, the 24-hour average downwind concentrations have been contoured and plotted rather than simply presented as the maximum predicted concentration.

Excavated material at Lower Monumental will be placed in three stockpiles (Appendix D, Annex B). An existing road used to access the up-slope stockpile was modeled. Other haul roads

will be used to construct levees and temporary cofferdams. This analysis assumed that one-half of all the excavated material passes over the modeled road.

Using the excavation schedule of 1,100 hours (55 days, 20-hour working days, Appendix D, Annex B), the estimated Lower Monumental haul road emissions were converted to units of grams per second per square meter (g/sec-m^2). The stockpile emission rates assume that one-half of the bulldozer, dumping, and grading emissions originate from the two large stockpiles. The quarry modeling assumed that the estimated emissions occurred over a 3-year period.

It is not necessary to model an entire road to predict excavation concentrations because maximum concentrations are adjacent to the fugitive dust sources. Emissions from the Lower Monumental haul road segments and stockpiles were modeled with ISCST3 (EPA, 1995c). Likewise, only a portion of a hypothetical quarry haul road was also modeled with ISCST3. According to the Guideline on Air Quality Models (40CFR Part 51 Appendix W), ISCST3 is appropriate for modeling regulated air pollutants from area sources in complex configurations. ISCST3 model options were consistent with the Guideline on Air Quality Models.

The modeling used meteorological data designed to produce the maximum possible concentration, consistent with EPA's screening procedures (EPA, 1992b). The worst case meteorology consisted of 54 combinations of wind speed and stability class for each of 36 wind directions. The modeling did not consider the frequency of occurrence of the conditions that are predicted to result in the maximum concentrations. One-hour concentrations were predicted at receptors located between the haul road and areas accessible to the public. The 1-hour concentrations were multiplied by EPA's time conversion factors (EPA, 1992b) to produce 24-hour concentrations, which were compared to the ambient air quality standard.

The quarry haul roads are also sources of PM_{10} emissions. The Quarry 2 haul road was modeled following the methodology presented above. In this case, it was assumed that quarry activities will continue for 3 years. A 4-mile haul road, with the excavation, rock crushing, and screening area on one end and the barge loading facility on the other end, was modeled using ISCST3 and worst-case meteorology. Results of the evaluation are presented as a contour plot of the maximum 24-hour PM_{10} concentrations.

Air quality regulations require that significant new sources not affect nonattainment areas without offsetting their emissions. To determine whether deconstruction emissions resulted in 24-hour concentrations greater than the 5 $\mu g/m^3$ significance level, Ice Harbor Dam, stockpiles, and haul roads were modeled as several large area sources. Input data included 6 years of hourly Yakima meteorological data. Maximum 24-hour concentrations were predicted for a line of receptors south of the construction site. Results are presented as a plot of concentration versus downwind distance.

The Snake River dam breaching effort is easier to visualize if it can be compared to similar projects. However, there are few dam removal projects available for comparison. The Elwha and Glines Canyon dams, located in the Olympic National Park, are slated for demolition. The Restoration Implementation Plan Environmental Impact Statement estimated haul road emissions and resulting ambient concentrations associated with the demolition of the two dams (National Park Service, 1996). The impacts associated with lower Snake River dam demolition will be compared to those of the Elwha and Glines dams. Demolition of the Lower Monumental dam would require excavation

of 30 times more material than demolition of both the Elwha and Glines Canyon dams. Air quality impacts associated with both projects are comparable.

3.2 Loss of Barge Traffic

In 1994, over 3.8 million metric tons (4.2 million tons) of freight passed through the locks at Ice Harbor Dam (Lee and Casavant, 1996). Nearly all of this commerce was downriver transportation of farm products. Waterborne transportation is characterized as follows:

- Farm products comprise 81 percent of the downriver transport and 78 percent of the total commerce.
- Forest products comprise 16 percent of the downriver transport and 15 percent of the total commerce.
- Petroleum products comprise 70 percent of the upriver transport and 3 percent of the total commerce.
- Fertilizers and chemical products comprise 14 percent of the upriver transport and less than 1 percent of the total commerce.
- Manufactured products comprise 14 percent of the upriver transport and 3 percent of the total commerce.

The Dam Breaching alternative would require a shift from barge transportation to train and truck transportation, which would change the quantity and distribution of vehicle emissions. Air emissions are estimated from the number of river, train, and road miles required to transport commodities affected by the Dam Breaching alternative. Data for this analysis are available from two sources. The Eastern Washington Intermodal Transportation Study (EWITS) conducted a number of studies, including an examination of energy consumption and air emissions associated with Snake River dam breaching. The Transportation Analysis (DREW, 1999b) provides the number of train and truck bushel-miles needed to transport the wheat and barley harvest following breaching. In addition, the change in the number of trucks hauling wheat and barley on selected Washington highways has been estimated.

3.2.1 Eastern Washington Intermodal Transportation Study

EWITS is a 6-year study jointly funded by the Federal government and the Washington State Department of Transportation. EWITS was established to facilitate existing regional and state-wide transportation efforts, forecast freight and passenger transportation service needs for eastern Washington, identify gaps in eastern Washington's current transportation infrastructure, and pinpoint transportation system improvement options critical to economic competitiveness and mobility. Data presented in several EWITS reports were incorporated into this emissions analysis.

EWITS examined the energy consumption and air emission impacts associated with Snake River dam breaching (Lee and Casavant, 1998). The study calculated the energy used and emissions created by three transportation modes (barge, train, and truck) for the 1994 eastern Washington wheat and barley harvest. Two cases were investigated: a base case modeled transportation modes currently available, and the second case examined the effects of not having barges available on the Snake River. The modeling was accomplished by using a Geographic Information System (GIS) database and a General Algebraic Modeling System (GAMS) optimization system. The GIS/GAMS

model determines minimum distances and least-cost routes and modes to transport wheat and barley from farms to Portland. The model organizes the data by ton-mile of wheat and barley, sorted by transportation mode. Energy consumption and emissions factors are expressed in units of ton-miles.

Comprehensive transportation modeling would account for a number of conditions, including vehicular performance, weight factors, infrastructure quality, pre- and post-trips, and climatic conditions. The GIS/GAMS modeling accounted for several of these factors. The Lee and Casavant study included two truck types, single unit three-axle trucks and combination tractor and trailer five-axle units, differentiated by their tare weight. Locomotive energy consumption and emissions data available from literature were used in the study (EPA, 1997b). Branch line locomotives are assumed to have the same characteristics as main line locomotives.

Comprehensive marine vessel emissions were not readily available until Lloyds Register published the results of a testing program in 1995. Additional emission testing has been conducted in California, Vancouver, B.C., and on Coast Guard vessels. Marine emissions are a function of vessel deadweight, engine horsepower, speed (for example, idle, maneuvering, cruise), and load. Towboat emissions used in the EWITS modeling are compatible with the following:

- British Columbia Ferries Emissions Test Program, by G. Rideout for the Environment Canada in 1998
- Commercial Marine Vessel Contributions to Emission Inventories, by Booz Allen & Hamilton for the EPA in 1991
- Emission Testing of Nonroad Compression Ignition Engines, by J. N. Carroll and C. M. Urban of the Southwest Research Institute for the EPA in 1995
- Port of Vancouver Marine Vessel Emissions Test Project, by G. Rideout and E. Radloff for the Environment Canada in 1997
- Shipboard Marine Engine Emission Testing for the United States Coast Guard, by Environmental Transportation Consultants for the Volpe National Transportation System Center and the United States Coast Guard Headquarters Navel Engineering Division.

Energy consumed and emissions from pre- and post-trip moves are ignored in the modeling study. Speed and road gradients are also not taken into account in the modeling. The model assumed that the entire crop was transferred to the Portland, Oregon, area for export, with no grain retained in storage. The model does not account for the possibility of railcar shortages. Finally, the study examined only the transportation of wheat and barley from the eastern Washington producing areas to the Portland seaport.

Air pollutant emission factors for diesel-fueled engines, available from EPA and others, are presented in units of pound of emitted pollutant per gallon of fuel (lb/gal). The uncontrolled emission factors were derived from EPA procedures for preparing mobile source emission inventories, and are presented in Table 3-6. Fuel usage for locomotives, trucks, and towboats were reported as the amount of energy required to move 0.9 metric tons (1 ton) of a commodity 1.6093 km (2 miles) (Btu/ton-mile). A British thermal unit (Btu) is the amount of energy required to raise the temperature of one pound of water one degree Fahrenheit (°F). One gallon of diesel fuel is equivalent to about 137,000 BTUs. Energy requirements by transportation mode are presented in Table 3-7. The Lee and Casavant study used uncontrolled emission rates.

Table 3-6. Mobile Source Emission Factors

			Emission Factors (lb/gal)		
Mode	**CO**	**VOC**	**NO_x**	**PM_{10}**	**SO_2**
Towboat	0.057	0.019	0.419	0.009	0.075
Locomotive	0.059	0.022	0.564	0.015	0.036
Truck, 3-axle	0.023	0.212	0.093	0.014	0.005
Truck, 5-axle	0.023	0.212	0.093	0.016	0.006

Sources: EPA, 1985, 1992, and 1997b; Lee and Casavant, 1998.

Table 3-7. Energy Requirements by Transportation Mode

Mode	Energy Requirement (Btu/ton-mile)
Towboat	374
Locomotive	372
Truck	551

Source: Lee and Casavant, 1998.

Air pollutant emissions for each transportation mode are determined as follows:

$$E_{ap} = EF_{ap} * T * M * EC / 137{,}000 \text{ Btu/gal}$$

where:

E_{ap} is the emission for each air pollutant, in lb

EF_{ap} is the emission factor for each air pollutant, in lb/gal (from Table 3-6)

T is the total tonnage for the transportation mode

M is the number of miles, and

EC is the energy consumed in Btu/ton-mile (from Table 3-7).

The GIS/GAMS model determined the optimal roads required to transport the grain harvest to elevators, the number of vehicles required to transport the harvest, and the emissions resulting from the trucks. Grain transportation from elevators to rail and river terminals and on to terminals in the Portland area was also simulated. Emissions from each transportation mode were summed. Total towboat, locomotive, and truck emissions, with and without the lower Snake River as a navigable waterway, were determined and are presented in Tables 3-8 and 3-9.

Table 3-8. Ton-miles for the 1994 Wheat and Barley Harvest with Snake River Barge Transportation

Mode	Wheat (million ton-miles)	Barley (million ton-miles)
Barge	827.4	76.3
Train	281.9	0.037
Truck	383.5	52.1
Total	**1,492.8**	**128.4**

Source: Lee and Casavant, 1998.

Table 3-9. Ton-miles for the 1994 Wheat and Barley Harvest without the Snake River Barge Transportation

Mode	Wheat (million ton-miles)	Barley (million ton-miles)
Barge	503.2	55.8
Train	545.5	0.093
Truck	442.8	108.1
Total	**1,491.5**	**164.0**

Source: Lee and Casavant, 1998.

Wheat and barley ton-miles were used to estimate transportation emissions. Wheat and barley currently accounts for about 80 percent of the Snake River commerce, all of which would be shifted to highways and railroads. By the time dam breaching and deconstruction become effective (2010), the amount of commodities normally shipped on the waterway is projected to increase. Furthermore, containers used to transport grain are often returned to the grain-producing areas empty. Therefore, to account for empty backhauls and provide a level of conservatism, the emissions were doubled. To account for all shipped commodities and the projected increase in shipments by 2010, the emissions were increased by 13 percent.

Although vehicles are sources of small amounts of GHG and HAP emissions, little data are available to quantify these emissions. EPA has CO_2 and organic compound emission factors for diesel fuel used in small stationary engines (EPA, 1998, Table 3.3-2 dated 10/96). These emission factors may be used to obtain order-of-magnitude estimates of the change in CO_2, benzene, and formaldehyde emissions with drawdown. According to the emission factors, CO_2 emissions are about 88 times larger than CO emissions. Benzene and formaldehyde emissions are about 0.003 times the vehicle VOC emissions, including exhaust, evaporative, crankcase, and refueling emissions.

3.2.2 Transportation Analysis

The Transportation Analysis (DREW, 1999b) is an assessment of the economic effects of dam breaching on regional transportation, including alternative shipping modes and costs, and a determination of the least-cost combination of storage, handling, and transport modes which would emerge in response to curtailment of waterborne transport. The economic analysis followed these steps:

- Identify the origins and destinations of commodity groups that use the lower Snake River.
- Develop costs for barge, train, and truck modes from transportation analysis models.
- Estimate transportation costs associated with the Existing Conditions and Dam Breaching alternatives with the assistance of a computer model.

Off-river origins of grain transported on the lower Snake River include areas within northeastern Oregon, eastern Washington, northern Idaho, and a small number of counties in the grain-producing areas of Montana and North Dakota. The economic analysis predicted barge bushel-miles for the Columbia and Snake Rivers before dam breaching and the change in barge, train, and truck bushel-miles after dam breaching. Following dam breaching, transportation on the Columbia River will continue. The bushel-mile data, generated by the transportation analysis and based on projected grain shipments for 2007, are presented in Table 3-10. Idaho truck bushel-miles are predicted to decrease as grain is hauled to closer elevators next to the railroads. The bushel-mile data are used to

estimate transportation-related air emissions. Only the change in bushel-miles was estimated by the Transportation Analysis. Total bushel-miles, with and without dam breaching, and the associated emissions were not estimated.

Table 3-10. Change in Transportation Bushel-Miles Resulting from Drawdown

Location	Barge Bushel-Miles Without Drawdown	Change in Bushel-Miles with Drawdown		
		Barge	Train	Truck
Columbia River	27,729,926,730	(8,041,678,752)		
Snake River	12,619,525,162	(12,619,525,162)		
Idaho			9,652,660,452	(1,643,257,066)
Montana				1,007,893,915
North Dakota				352,942,345
Oregon				40,175,108
Washington			5,915,367,218	3,429,355,830

Source: DREW, 1999.

The limitations of the economic analysis are reflected in the emissions data. The economic analysis does not attempt to determine the extent that exports from the region may decline as a consequence of higher transportation costs. Non-grain commodities are not included. As inland navigation capacity is reduced, it is assumed that competing surface transportation modes possess the required capacity or that they would add the capacity necessary to accommodate additional traffic. Market practices such as backhauls are incorporated in truck movements to the extent possible.

Barge bushel-miles without drawdown and the change in barge, train, and truck bushel-miles were converted to ton-miles and multiplied by the EWITS emission factors. The emissions were doubled to account for towboats, locomotives, and trucks returning empty containers and were increased by 13 percent to account for other commodities normally shipped on the river.

This analysis produced two estimates of transportation-related air emissions, based on the EWITS and the Transportation Analysis, which use different input data, methods, and assumptions. Therefore, the results represent two possible air quality consequences following drawdown. Air emissions estimated from the two transportation analyses are averaged for the Existing Conditions and Dam Breaching alternatives.

3.2.3 Estimated Truck Counts Resulting from Drawdown

Grain harvested in eastern Washington is currently trucked from farms to elevators and on to river ports or to the Tri-Cities area. With drawdown, grain would be trucked to elevators located next to rail lines or would be trucked directly to the Tri-Cities area. Lee and Casavant (1998) modeled wheat and barley quantities on eastern Washington highways with and without the Snake River waterway. These grain quantities are combined with WSDOT traffic counts on selected highways to estimate the change in the number of trucks.

Vehicle and truck counts at selected locations for 1999 are presented in Table 3-11 (WSDOT, 2000). EWITS Modeling estimated the number of grain bushels on these roads (Lee and Casavant, 1998). The modeled number of bushels was converted to the number of trucks by assuming 60 pounds per bushel and 26 tons per truck load (DREW, 1999b). The projected number of trucks hauling grain was combined with the actual average daily truck counts to estimate the change in the number of trucks at select locations following drawdown.

Table 3-11. Traffic Counts

Highway	Intersection	Average Number of Vehicles per Day	Average Number of Trucks per Day
US 395	SR 26	6,200	2,480
	SR 260	5,400	2,160
SR 127	SR 26	1,000	290
SR 195	SR 272	12,000	1,920
SR 26	US 395	1,500	375
	SR 195	2,300	575
SR 260	West of US 395	3,400	884
	East of US 395	750	195

Source: WSDOT, 2000.

3.2.4 Transportation-Related Impact Analysis

Although transportation-related emissions are generated over large areas, it is not practical to assume that the emissions originate from all areas of eastern Washington. Because the sources would be spatially separated, the critical receptors would be located within the source area, and this approach would not account for the variations in wind conditions and topography within the source area. An attempt to model emissions from individual navigation channels, railroads, and highways throughout eastern Washington would overwhelm the capabilities of the dispersion models.

In view of these difficulties, the selected approach involves modeling individual transportation corridors that may result in ambient concentrations that approach or exceed the air quality standards in the immediate vicinity of the sources. Ambient concentrations resulting from towboat emissions upstream of the Ice Harbor Dam and highway emissions for the intersection of US 395 and SR 260 will represent emissions for the Existing Conditions alternative. Vehicle emissions for the US 395 and SR 260 intersection with the addition of 1,005 grain trucks per day, for the September through December period, will represent emissions for the Dam Breaching alternative.

Ambient Air Quality Impacts Resulting from Towboat Emissions

Ambient concentrations resulting from towboats traveling downstream and upstream on the Snake River were predicted using EPA's CALINE3 model (Benson, 1979). CALINE3 is appropriate for mobile sources with uninterrupted traffic flows (40CFR Part 51, Appendix W, Guideline on Air Quality Models). The downstream and upstream navigation channels were modeled as independent sources. Emissions were those estimated from the transportation analysis. Meteorological data used in the modeling maximized ambient concentrations and included low wind speeds (1 m/sec), stable atmospheric conditions (stability class F, very stable), and an onshore wind direction (a wind direction 45 degrees to the shoreline produces the largest concentrations). CALINE3 predicts 1-hour CO concentrations, which were converted to longer averaging periods by EPA multiplying factors (EPA 1992b). Concentrations of other pollutants were estimated by multiplying the CO concentrations by the ratio of emissions to the CO emissions.

During foggy conditions, towboats are moored at the hard rock dolphins just upstream of the Ice Harbor dam. Emissions from idling towboat engines may contribute to ambient concentrations at the nearby shoreline. Emissions for large diesel engines are estimated from emissions factors obtained from EPA (EPA, 1998, Table 3.4-1 dated 10/96). It is assumed that six towboats are moored and the idling engines each generate 300 horsepower (hp). The estimated emissions are

modeled as a 24,104 m^2 elevated area source with SCREEN3 (EPA, 1995a). The SCREEN3 model determines the meteorological conditions that will produce the maximum concentration independent of wind direction. The 1-hour concentrations predicted by SCREEN3 were converted to other averaging periods by the EPA multiplying factors. Fog conditions that make navigation impossible occur during a limited number of days per year. The average numbers of days with visibility less than one-quarter mile are 31, 45, and 19 for Pendleton, Spokane, and Yakima, respectively (Annex A). The predicted long-term average concentrations are 45-day averages.

Ambient Air Quality Impacts Resulting from Highway Emissions

US 395 is a four-lane road with entrance and exit ramps that connect to the two-lane SR 260. With the Dam Breaching alternative, this intersection will experience additional grain-truck traffic. Higher emissions are expected where signalization creates queues of idling vehicles, which leads to higher ambient concentrations of air pollutants. The US 395 and SR 260 intersection was modeled to estimate traffic-related ambient concentrations. The modeling included traffic control lights at the intersections of the entrance and exit ramp with SR 260. A total of 16 roadway links were modeled. Receptors were placed 30 feet from the roadway.

The WSDOT vehicle counts are presented in Table 3-11. The traffic counts have increased little over the last several years. Therefore, 1999 traffic counts were used in the analysis. It was assumed that the traffic flow was equal in both directions. The maximum 1-hour vehicle counts were assumed to be 10 percent of the total average daily volumes. The WSDOT traffic volumes also indicate the number of trucks, which were used to estimate a vehicle mix.

Vehicle emissions were estimated using MOBILE5, EPA's mobile vehicle emissions model (EPA, 1994). Model input data include the vehicle mix as a percent of the total, categorized by fuel and vehicle size. MOBILE5 predicted emissions representative of a fleet of vehicles in 2010, late fall and early winter temperatures, vehicle speeds of 50 and 25 mph, and idle emissions. MOBILE5 was re-run with a vehicle mix that included an additional 1,005 trucks per day.

MOBILE5 was used to estimate CO, NO_x, and VOC emissions. PM_{10} and SO_2 emissions were estimated from small gasoline and diesel engine emission factors (EPA, 1998, Table 3.3-1, dated October 1996). The ratio of the SO_2 to the NO_x gasoline and diesel emission factors was multiplied by the MOBILE5 NO_x emission to estimate SO_2 emission rates. Similarly, PM_{10} emission rates were estimated from the ratio of the SO_2 to the PM_{10} gasoline and diesel emission factors. The vehicle emissions used in the modeling, in units of grams per vehicle mile (VM) or grams per hour, are presented in Table 3-12.

According to the EWITS modeling, there would be little change in the number of trucks on SR 260 following dam breaching. Therefore, the emission factors for the SR 260 roadway links would not change. Following dam breaching, the traffic on US 395 is projected to increase by 1,005 trucks per day. Because the percent of trucks increases with dam breaching, the MOBILE5 emission factors reflect the change in vehicle mix.

Vehicle emissions were modeled using CAL3QHC (EPA, 1995b; Eckhoff and Braverman, 1995), which combines the CALINE3 line source model with a traffic model that calculates delays and queues at signalized intersections (40CFR, Part 51, Appendix W, Guideline on Air Quality Models). CAL3QHC uses sequential hourly meteorological data. For this application, the 8 years of Spokane

data were used to model vehicle emissions, with and without additional trucks as a consequence of drawdown.

Even though traffic volumes in 2010 will be greater than those modeled, the emissions and concentrations are considered conservative. The maximum 1-hour, 3-hour, and 8-hour concentrations were predicted to occur at night when traffic volumes are smaller. Constant 1-hour traffic volumes were modeled with no hour-by-hour, day-by-day, or week-by-week variation.

Table 3-12. Highway Emissions Used in Modeling

Route	Vehicle Speed	Units	CO	NO_x	PM_{10}	SO_2	VOC
Without Drawdown							
US 395	50 mph	(g/VM)	8.22	4.48	0.306	0.269	1.05
	35 mph	(g/VM)	11.7	3.82	0.261	0.229	1.37
	Idle	(g/hour)	229.2	17.8	1.22	1.07	20.5
SR 260	35 mph	(g/VM)	13.6	3.14	0.214	0.188	1.44
	25 mph	(g/VM)	20.2	3.23	0.220	0.193	1.91
	Idle	(g/hour)	273.5	14.0	0.957	0.841	23.8
With Drawdown							
US 395	50 mph	(g/VM)	7.76	5.09	0.347	0.305	1.05
	35 mph	(g/VM)	11.4	3.95	0.269	0.237	1.36
	Idle	(g/hour)	207.2	20.5	1.40	1.23	19.1
SR 260	35 mph	(g/VM)	13.6	3.14	0.214	0.188	1.44
	25 mph	(g/VM)	20.2	3.23	0.220	0.193	1.91
	Idle	(g/hour)	273.5	14.0	0.957	0.841	23.8

3.3 Windblown Fugitive Dust

In the past, the Corps has received public comments regarding fugitive particulate matter associated with drawdowns of Lake Koocanusa. Residents of Eureka, Montana, about 13 km (8 miles) east of the reservoir, believe that the seasonally exposed reservoir sediments significantly contribute to blowing dust problems. In response to this concern, the Corps conducted a PM_{10} monitoring program in the Eureka/Lake Koocanusa area (Environalysis, 1996). Studies have also been conducted to address windblown dust problems at Owens Lake in California and in eastern Washington. These studies, plus emission estimating methods recommended by EPA, are used to develop emission estimates from exposed dry lake sediments and to predict PM_{10} concentrations resulting from these emissions.

3.3.1 Windblown Emissions

Without the advantage of onsite data, it is difficult to estimate PM_{10} concentrations expected from windborne fugitive dust. Particulate matter concentrations are a function of many variables, including:

- The area of exposed dry sediments
- The amount of fine particulate matter in the sediments
- The sediment moisture content

- The frequency that the surface is disrupted, providing fresh material for wind erosion
- The frequency and duration of winds strong enough to lift erodible particles
- The roughness of the exposed surface (a smooth surface versus one impregnated with rocks and other obstacles).

To gain some understanding of the nature of the blowing dust problem as it may apply to the lower Snake River reservoirs, the impact evaluation includes an example of a PM_{10} emission calculation. Wherever possible, information relevant to the lower Snake River reservoirs is included in the analysis, along with a description of the representativeness and limitations of the data.

Wind-generated erosion depends on the amount of erodible material present, the roughness of the surface, the surface wind speed, and the frequency with which the surface is disturbed. Particulate matter emission rates would rapidly decrease as the erodible material is removed from the surface. If the surface remains undisturbed or wet, the amount of erodible material is limited. EPA has developed a method to predict the amount of particulate matter emitted during a wind erosion event (EPA, 1998). The method used to estimate PM_{10} emissions and the frequency that they occur is summarized as follows:

- Determine an appropriate threshold frictional velocity, a measure of the wind stress on the erodible surface, for the dry sediments.
- Determine the maximum fastest mile. Emissions resulting from this wind speed represent an upper limit of fugitive emissions in the region.
- Determine a relationship between the peak gusts and 1-hour average wind speeds. It is assumed that this relationship is true for the fastest mile, the variable appropriate for the maximum emissions.
- Convert the threshold frictional velocity to a 10-meter measurement, and convert this value to an equivalent 1-hour average wind speed.
- Scan the meteorological database and determine the number of wind speed observations greater than the threshold frictional velocity.
- Compute hourly emission factors for frictional velocities that range from the threshold frictional velocity to the maximum fastest mile.
- Estimate hourly PM_{10} emissions from the emission factors, hourly meteorological data, and the area of exposed sediments.
- Sum the hourly emissions and compute an annual average PM_{10} emission rate for the four reservoirs.

The frictional velocity is a measure of the wind stress on the erodible surface. The threshold frictional velocity represents the wind shear necessary to begin to move the erodible surface particles. If the frictional velocity exceeds the threshold frictional velocity, wind erosion would occur. The frictional velocity is a function of the material being eroded. For silty clay soils typical of the material that may be found in sediments, the threshold frictional velocity is 0.64 m/sec (1.43 mph) (Gillette, 1988).

The meteorological variable that best reflects the magnitude of wind gusts that lift surface dust is the fastest mile (EPA, 1998). This quantity represents the wind speed corresponding to a mile of wind movement past the anemometer in the least amount of time. Fastest mile measurements for the three meteorological monitoring stations used in this study (Pendleton, Spokane, and Yakima) are available for periods on the order of 40 years (see Annex A). The highest fastest mile value is 34.4 m/sec (77 mph).

The fastest mile, measured at a height of about 10 meters above the surface, is not representative of near-surface wind speeds. By assuming a logarithmic wind speed profile, the near-surface frictional velocity may be estimated (EPA, 1998):

$$u_{fv} = 0.053 * u_{fm}$$

where u_{fv} = frictional velocity (m/sec)

u_{fm} = fastest mile at 10 m (m/sec)

The expression above is valid for a surface roughness of 0.5 cm. Surface roughness is proportional to the dimension of the objects penetrating the surface. A low surface roughness is assumed for smooth sediments. The expression above can be used to convert the threshold frictional velocity to a 10-meter wind speed and the fastest mile to a frictional velocity. The frictional velocities range from 0.64 to 1.82 m/sec (1.43 to 4.08 mph). The corresponding 10-meter fastest miles range from 12.1 to 34.4 m/sec (27.1 to 77.0 mph).

The meteorological database used in this analysis corresponds to the period when peak gusts began to be included in the climatic summaries. Assuming that the maximum 1-hour wind speed for a particular month includes the peak gust, a relationship between peak gusts and 1-hour average wind speeds was developed (Figure 3-1). Hourly average wind speeds are about 62 percent of the peak gusts. The hourly average wind speeds corresponding to the threshold and maximum frictional velocity can then be determined. This assumes that the expression above, used to convert fastest mile measurements to frictional velocities, is valid for peak gusts. The corresponding threshold and maximum 1-hour wind speeds measured at 10 meters are 7.47 and 21.2 m/sec, respectively (16.7 and 47.5 mph).

Mean atmospheric winds are not sufficient to sustain wind erosion. However, wind gusts may quickly deplete a substantial portion of the material available for erosion. Historical measurements of the peak gust are available in annual climatological summaries for Pendleton, Spokane, and Yakima (see Annex A). These data represent short-period wind speeds. Sustained high-speed wind events are also an important mechanism for suspending large amounts of dry lake sediments. The meteorological database used to develop the Pendleton, Spokane, and Yakima windrose figures (Section 2) was scanned to determine the frequency of occurrence of 1-hour average winds greater than the threshold frictional velocity. For all three meteorological monitoring locations, the number of hours of high wind speeds quickly decreases with increasing speeds (Figure 3-2). Wind events strong enough to move surface material occur at a frequency of between 5 and 10 percent of the hours in a year. Hourly average wind speeds greater than 16 m/sec (36 mph) occur about once per year.

The amount of material removed from the surface is a function of the difference between the wind velocity at the surface and the velocity required to erode the surface and may be expressed as follows (EPA, 1998):

$$EF_F = k * (58(u_{fv} - u_{tv})^2 + 25(u_{fv} - u_{tv}))$$

where EF_F = emission factor, in grams per square meter (g/m^2)

k = dimensionless aerodynamic particle size multiplier

u_{fv} = frictional velocity, in m/sec

u_{tv} = threshold frictional velocity, in m/sec

The expression above is valid for dry exposed material with limited erosion potential. The frictional velocity above is derived from the fastest mile. The emission expression assumes that the largest wind speed event between surface disturbances removes all available erodible material. If the surface is disturbed again, additional material becomes available for erosion by the next high wind event.

The amount of sediment with particle diameters less than 10 microns would be similar to the suspended load in the lower Snake River. Particle size distribution measurements indicate that about 20 percent of the particles are less than 10 microns. For this study, the value of k in the emission factor expression above is equal to 0.2.

The expression above was used to compute PM_{10} emission factors, in units of g/m^2, as a function of average 1-hour wind speeds greater than the threshold frictional velocity. The emission factors are presented in Figure 3-3. Emission factors used in this study are comparable to the calibrated CP^3 dust emissions (Claiborn et al., 1998). Actual emissions would also depend on the amount of dry sediments available. After the lighter surface material has been removed, additional material would not be available until the surface is disturbed. This analysis assumes that the amount of erodible material is not limited.

Annual windblown emissions are calculated from wind speed-dependent emission factors, the number of hours of wind speeds greater than the threshold frictional velocity, and the area of exposed dry sediments. The surface area of each of the four lower Snake River reservoirs is presented in Table 3-13.

According to Appendix D, Natural River Drawdown Engineering, re-vegetation would be accomplished in the following phases:

- Initial seeding at 2-week intervals would take place during the drawdown period.
- Drill seeding would be performed during the following spring to revegetate areas where the initial seeding was not successful.

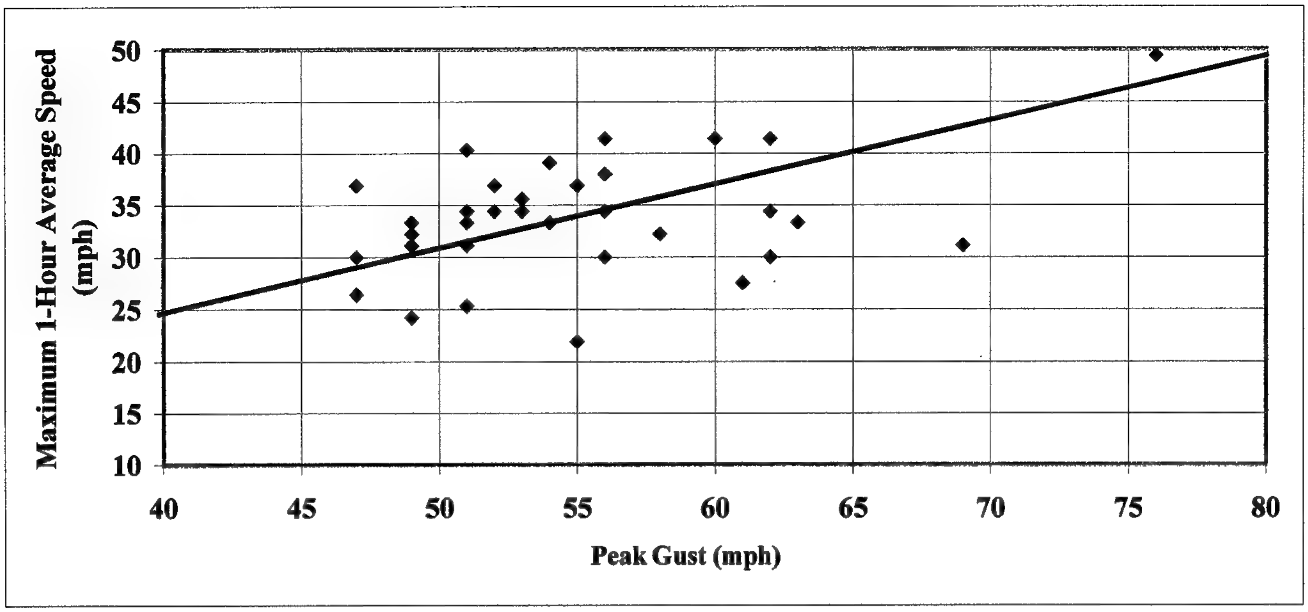

Figure 3-1. The Relationship Between Peak Gusts and One-Hour Average Wind Speeds

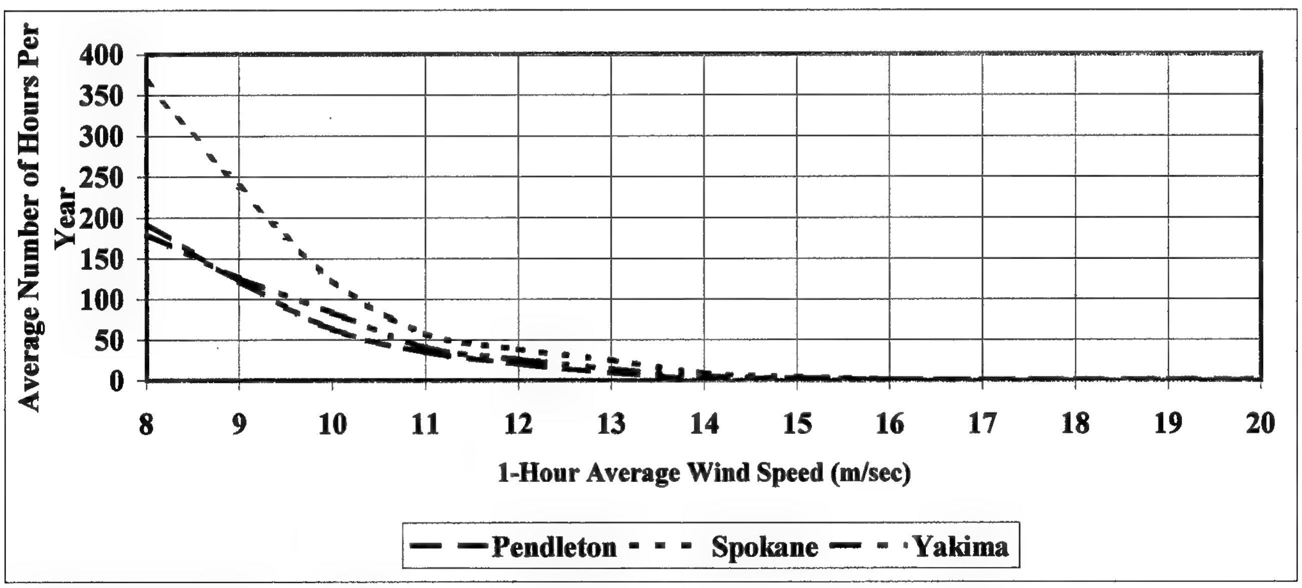

Figure 3-2. Average Number of Hours Per Year of High Wind Speed Events

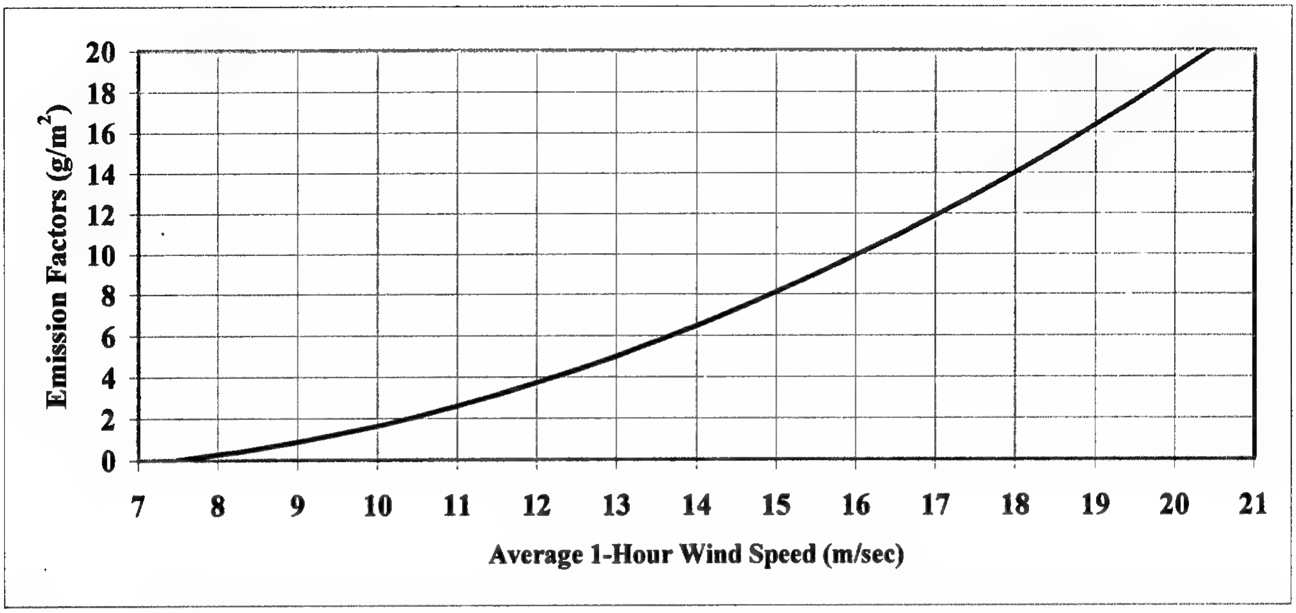

Figure 3-3. PM_{10} Emission Factors by 1-Hour Average Wind Speed

- Trees would be planted during the second spring following drawdown.
- Annual efforts would be made to reestablish vegetation in problem or disturbed areas.

Table 3-13. Area of Lower Snake River Reservoirs

Facility	Area Acres	Area m^2	Area km^2
Ice Harbor	8,375	33,892,558	33.9
Lower Monumental	6,590	26,668,890	26.7
Little Goose	10,025	40,569,898	40.6
Lower Granite	8,900	36,017,166	36.0
Total	**33,890**	**137,148,526**	**137.1**

The entire area of each reservoir would not be exposed to wind erosion at one time. Therefore, the amount of dry lake sediments exposed to erosion would be less than the values presented in Table 3-13. Furthermore, the Corps would restrict access to the lake sediments, further limiting surface disturbances and the availability of erodible material. Test areas at Owens Lake indicate that a 99 percent reduction in emissions is possible with only 50 percent of the dry sediment covered by vegetation. This analysis conservatively assumes that these measures to reduce wind erosion would reduce emissions by 90 percent.

3.3.2 Windblown Fugitive Dust Concentrations

The CP^3 investigated windblown dust episodes in eastern Washington using the following models and techniques (Claiborn et al., 1998):

- CALMET, a three-dimensional meteorological model with a detailed boundary layer module, which is designed for use in complex terrain. The model uses gridded wind speed and direction data in 10 vertical layers.
- EMIT, a dust emissions model, which uses land use and soil type data on a 1 km by 1 km grid.
- CALGRID, a three-dimensional transport model incorporating gravitational settling, which operates on a 4 km grid.
- Land use and soil type data with 1 km resolution, which is derived from satellite imagery and refined with ground truth.
- Emission factors for various soil types, which are derived from measurements with a portable wind tunnel.

The area from the eastern base of the Cascade Mountains to the western side of the Bitterroot Mountains in Idaho was included in the modeling. PM_{10} concentrations resulting from several eastern Washington storms were modeled. The results were calibrated with concentrations measured in Kennewick and Spokane. The modeling results are presented in Annex C. Figures C-1 through C-3 represent wind storms for the Existing Conditions alternative. Figure C-4 presents PM_{10} concentrations resulting from Snake River reservoir sediment emissions. PM_{10} concentrations representative of the Dam Breaching alternative are presented in Figure C-5. For one storm the

modeling was repeated with a modified line of grid cells from Pasco to Lewiston to approximate the Snake River. The soil type for these grid cells was modified to very erodible conditions.

The CP^3 modeling predicted PM_{10} concentrations from dry reservoir sediments during high wind speed events. Should the dust contain contaminants, residents along the reservoirs may be at risk from hazardous and toxic air pollutants. Ecology regulates TAP sources and has developed Acceptable Source Impact Levels (ASIL), risk-based ambient concentrations. The risk to an individual exposed to a pollutant is less than one-in-one-million if the ambient concentration is less than the ASIL. The metal and organic (dioxin and DDT) concentrations equal to their corresponding ASIL concentrations were determined from the predicted PM_{10} concentration (the ratio of ASIL to the predicted dust concentration, in units of ppm).

Appendix C to the FR/EIS describes water quality and sediment field investigations within the Columbia Basin. Laboratory analysis of sediment samples from the lower Snake River is also described and summarized. The metals and organic concentrations in sediment necessary to produce air concentrations equal to ASIL concentrations were estimated from the predicted PM_{10} concentrations. This assumes that all of the sediments exhibit contaminant concentrations equal to the maximum measured concentrations. The sediment concentrations were used to determine whether the windblown dust concentrations could result in ambient metals and organic concentrations greater than the ASILs.

3.4 Replacement Power Generation

Hydropower generation is a "clean" power source. The power-generating capacity of the Snake River hydropower facilities would be replaced under the Dam Breaching alternative. New thermal power plants would result in an increase of criteria air pollutants, TAPs, and GHGs. The Technical Report on Hydropower Cost and Benefits (DREW, 1999a) investigates the economic consequences of the loss of hydropower and evaluates the power production alternatives.

Electricity is bought and sold throughout the western United States and parts of Canada and Mexico. Changes in power production in the Pacific Northwest could result in changes to power production, and hence atmospheric emissions, in all regions of the Western System Coordinating Council (WSCC). WSCC electric generating resources include roughly 2,000 thermal power plants that burn coal, natural gas, and oil (DREW, 1999a). This air quality analysis attempts to estimate how emissions would change on a regional basis because of the loss of the lower Snake River hydropower and is based on the findings of the Technical Report on Hydropower Cost and Benefits.

The Technical Report on Hydropower Cost and Benefits (DREW, 1999a) investigates how the current power system functions and how the system would change under Alternative 4—Dam Breaching. Models are used to assist with the analysis. Hydro regulation models determine how much hydropower generation would occur for different water years and various Feasibility Study alternatives. Power system models estimate the generating resources required to meet demand. The power system models incorporate changes resulting from deregulation of the electrical industry and changes in the wholesale power market. The power system models also include economic factors such as fuel costs and the marginal cost of production. The power system model PROSYM incorporates fuel costs, variable operating and maintenance costs, and startup costs for each generating unit, and it has an air pollution emission subroutine. Fuel type, heat rate, down time, output, and the retirement date of the generating units are included in the model. The generating

units are dispatched by PROSYM in order of increasing costs, unless fuel supply contracts or other factors require a specific dispatch.

PROSYM predicts which of the approximately 2,000 WSCC generating units would be used to meet power demands on an hour-by-hour basis. The determination of which generating units are on-line is performed primarily by economic factors: the least costly units are turned on first, and the older, less efficient, plants with greater emissions are turned on last. The number of operating hours per year is determined for each of the approximately 2,000 WSCC generating units. Air emissions are estimated from actual emission rates for each of the thermal generating units multiplied by the predicted number of operating hours for that unit. The emission factors are obtained from actual emissions reported to EPA in annual emission reports. Currently, the model is limited to CO_2, NO_x, and SO_2 emission factors. Details regarding the PROSYM model are presented in the DREW report (1999a).

Over time, new power plants would be built throughout the WSCC to meet growth demand under all the alternatives. The PROSYM model uses a market price approach to determine costs associated with replacement power generation. It is assumed that the new plants would be natural gas-fired, combined-cycle combustion turbines, currently the most economically feasible power plants being built. The new plants are assumed to have emission factors equal to the latest combined cycle plants built in each WSCC region.

PROSYM evaluated generating capacity requirements for several cases:

- A1 – The Snake River hydrofacilities are in place. This case represents the Existing Conditions alternative projected to 2010.
- A2 – The Snake River hydrofacilities are in place and include fish passage enhancements. This case represents Major System Improvements alternative projected to 2010.
- A3 – The Snake River hydrofacilities are breached. This case represents the Dam Breaching alternative projected to 2010.

Slightly more hydropower would be generated with case A2. The change in emissions from case A1 to A2 is very small and was not quantified by the Power System Analysis. Case A3 consists of 1,550 peak megawatts (MW) of replacement capacity. All new power plants would be built somewhere in the Pacific Northwest. The demand for energy will continue, resulting in a need for additional generating capacity. All cases include additional natural-gas-fired, combined-cycle, combustion turbine power plants, which will go online by 2010, with or without Snake River hydropower.

As discussed in Section 2.1.5, the siting of new power plants may be a critical factor. It is assumed that new power plants added to the regions would meet all applicable Federal, state, and local air quality regulations. It must be emphasized that the results of the analysis are hypothetical. The real world response to increasing power demand, with and without the loss of lower Snake River hydropower, may be different than predicted in the WSCC regions. The PROSYM emission estimates are representative of 2010, based on projected population growth and energy requirements.

The PROSYM model estimates CO_2, NO_x, and SO_2 emission from thermal power plants in the western United States. These estimates are extrapolated to include CO, VOCs, PM_{10}, and other

pollutants by use of published emission factors. Coal, fuel oil, and natural gas emission factors are available from EPA (1998). The emission factors depend on firing practices (dry bottom firing, tangentially fired, and spreader stoker) and control technologies (cyclones, multiple cyclones, scrubbers, precipitators, and baghouses). Average uncontrolled emission factors for coal, natural gas, and fuel oil combustion are presented in Table 3-14. These criteria and HAP emission factors assume an average sulfur content for coal, natural gas, and oil equal to 3, 1.0, and 1.0 percent, respectively.

To determine emissions of other pollutants, the estimated CO_2, NO_x, and SO_2 emissions were multiplied by the ratio of the emission factors. For example, to estimate CO emissions for natural gas combustion, the natural gas CO_2 emissions were multiplied by the natural gas CO emission factor and divided by the natural gas CO_2 emission factor. NO_x emissions were used to derive VOC, benzene, and formaldehyde emissions (all of these pollutants are ozone precursors). PM_{10} emissions were derived from SO_2 emissions (lean fuels such as natural gas emit very few of these pollutants). This approach assumes that emission controls applied to CO_2, NO_x, and SO_2 emissions apply to other pollutants. CO emissions will be overestimated because CO_2 is not normally controlled.

Table 3-14. Average Uncontrolled Combustion Emission Factors

Pollutant	Coal Combustion (lb/ton)	Natural Gas (lb/hp-hour)	Fuel Oil (lb/hp-hour)
CO	5.5	0.000860	0.000384
CO_2	5652.5	0.876	1.32
NO_x	16.4	0.00353	0.00560
PM_{10}	11.9	0.000335	0.000489
SO_2	110.7	0.000226	0.00809
TOC	0.24	0.000192	0.000137
Benzene	0.0013	-	-
Formaldehyde	0.00024	0.0000216	0.0000104

Source: EPA, 1998.

The independent power producers (IPP) frequently have a mix of generating types. Pacific Gas and Electric (PG&E) and Southern California Edison (SCE) have mostly natural gas-fired units, with a few coal combustion units. These resources have been treated as all natural gas units in this analysis. San Diego Gas and Electric (SDG&E) operates only natural gas-fired plants.

4. The Alternatives and Their Impacts

This chapter compares air quality impacts associated with the Existing Conditions, Major System Improvements, and Dam Breaching alternatives. The Existing Conditions alternative includes an estimate of emissions associated with current conditions.

4.1 Existing Conditions Alternative

For the Existing Conditions alternative, the lower Snake River facilities would remain in place and barge traffic would continue on the Snake River waterway. No changes are planned under this alternative. Emissions estimates presented in this alternative represent existing conditions or emissions representative of a base line year.

4.1.1 Demolition-Related Fugitive Emissions

Construction and demolition activities would not take place under the Existing Conditions alternative. Therefore, no demolition-related atmospheric emissions would result from this alternative.

4.1.2 Loss of Barge Transportation

Barge transportation on the navigable portions of the Columbia and Snake rivers would continue under the Existing Conditions alternative. Although there would not be any new air quality impacts, emission estimates for this alternative are used to predict the changes associated with the Dam Breaching alternative. Emissions have been estimated from two data sources. The EWITS and Transportation Analysis studies use different methods to estimate transportation-related impacts for the Dam Breaching alternative. Methods used to estimate air emissions were presented in Section 3.

4.1.2.1 Eastern Washington Intermodal Transportation Study

The Corps tracks freight shipments by commodity through the lower Snake River locks. These data were assembled as part of an EWITS investigation of waterborne commerce. Upriver and downriver commodity tons for each of the lower Snake River dams are presented in Table 4-1 (Lee and Casavant, 1996). Table 4-1 is based on 1994 data, the same year for which wheat and barley transportation were modeled (Lee and Casavant, 1998). The 1994 harvest consisted of about 132 million bushels of wheat and 17 million bushels of barley.

There are 20 grain-producing counties in eastern Washington. Grain movements begin at the farm and pass through 695 township centers and 400 grain elevators. The next destination is elevators at river ports or rail lines. Intermediate destinations include short- and long-term storage stations and consolidation points. About 60 percent of the harvest is shipped from production areas to elevators; the remaining 40 percent is trucked directly to river ports (Jessup, Ellis, and Casavant, 1997). Production areas located away from the Snake River ship grain by truck to intermediate storage or elevators adjacent to railroads. Barley is divided between township to river port elevators (62 percent) and township to feedlot (38 percent) shipments.

Table 4-1. Lower Snake River Commodity Tonnage for 1994

	Upriver				Downriver			
Commodity	Ice Harbor	Lower Monumental	Little Goose	Lower Granite	Ice Harbor	Lower Monumental	Little Goose	Lower Granite
Gasoline, jet fuel, kerosene	48,494	48,494	48,494	48,494	226	226	226	226
Distillate, residual, other fuels	80,577	80,577	80,577	80,577	35	35	35	35
Petroleum pitches, asphalt, naphtha	1,230	1,230	1,230	1,230	0	0	0	0
Fertilizer	23,139	24,232	24,232	7,232	500	500	500	0
Organic industrial chemicals	2,840	2,840	2,850	2,850	242	242	242	242
Forest products	1,596	1,596	1,596	0	636,627	711,051	710,376	704,204
Pulp and waste products	0	0	0	0	11,426	11,426	11,426	11,426
Sulfur, clay, salt	0	0	0	0	7,436	7,436	7,436	7,555
Paper and allied products	0	0	0	0	99,289	99,077	99,083	98,200
Primary non-ferrous metal products	20,743	21,732	22,621	23,203	1,818	1,624	1,559	1,674
Primary wood products	0	0	0	0	15	15	15	15
Wheat	4,200	4,100	14,700	600	3,060,772	2,460,057	2,318,521	1,209,057
Rye, barley, rice, sorghum, oats	0	0	0	0	136,392	138,664	130,664	51,022
Oilseed (soybean, flaxseed, others)	0	0	0	0	3,750	3,750	3,750	3,833
Vegetable products	0	0	0	0	56,788	57,081	57,091	57,989
Animal feed, grain mill products, flour	0	0	0	0	1,593	1,593	1,593	1,593
Other agricultural products	0	0	0	0	69	69	69	69
Barged fish	0	0	0	0	698	618	478	0
Manufactured equipment, machinery	1,800	1,800	1,800	30	805	156	156	136
Commodity unknown	2,955	1,230	1,230	0	1,322	456	456	341
Total	**187,574**	**187,831**	**199,330**	**164,216**	**4,019,803**	**3,494,076**	**3,343,676**	**2,147,617**

Source: Lee and Casavant, 1996.

Grain loaded onto barges travels by river to Portland, Oregon. Grain trucked to intermediate storage locations is subsequently trucked to elevators with rail loading facilities. Grain loaded onto railroad cars is unloaded at export elevators in the Portland area.

In the energy consumption and emissions study, commodity movements were expressed as ton-miles by transportation mode (Lee and Casavant, 1998). Ton-miles for the 1994 wheat and barley harvest by transportation mode are shown in Table 3-8. Transportation-related air emissions for wheat and barley shipments are shown in Table 4-2.

Table 4-2. Unadjusted Wheat and Barley Transportation-Related Emissions for Snake River Towboats

		Emissions (tons)				
Mode	**Commodity**	**CO**	**VOC**	**NO_x**	**PM_{10}**	**SO_2**
Barge	Wheat	64	21	473	10	85
	Barley	6	2	44	1	8
Train	Wheat	23	8	216	6	14
	Barley	0.003	0.001	0.028	0.001	0.002
Truck	Wheat	18	164	72	12	5
	Barley	2	22	10	2	1
Total		**113**	**218**	**814**	**31**	**112**

Source: Lee and Casavant, 1998.

About 80 percent of the wheat harvest is transported to Portland by barge. Towboats on the Columbia and Snake Rivers account for the greatest amount of emissions from wheat shipment. About 20 percent of the harvest arrives in Portland by rail. Trucks are used to move the harvest from producers to storage locations and on to river or rail terminals. The emissions presented in Table 4-2 are underestimated because the EWITS modeling did not include barge, train, and truck return trips and considered only wheat and barley. Most of the Portland-bound barges and rail cars return empty to eastern Washington.

According to Lee and Casavant (1996), wheat and barley account for about 78 percent of the total downriver commerce passing through the Bonneville locks. Downriver transportation far exceeds the upriver movement. It is assumed that upriver shipments include empty barges (and, by inference, rail cars and trucks). Because wheat shipments dominate the eastern Washington to Portland commerce, it is assumed that total transportation-related emissions, estimated by EWITS, can be increased by an additional:

- 100 percent to account for barge, rail, and truck return trips and the Portland to eastern Washington shipments (this is an extreme estimate, especially for trucks)
- 13 percent to account for the other commodities and to project the shipments to levels representative of 2010.

Based on the EWITS data, transportation-related air emissions, adjusted for the above factors, are as follows:

Pollutant	CO	VOC	NO_x	PM_{10}	SO_2
TPY	260	500	1,872	71	256

Trucks are used to haul grain from producers and intermediate storage locations to elevators adjacent to railroads and waterways. The flow over eastern Washington highways was simulated as part of the EWITS GIS/GAMS modeling effort (Jessup, Ellis, and Casavant, 1997). Maps showing wheat and barley highway flows for the Existing Conditions alternative are reproduced in Annex B.

4.1.2.2 Transportation Analysis

The Transportation Analysis (DREW, 1999b) estimated 2007 barge bushel-miles without dam breaching, and the change in barge, train, and truck bushel-miles following dam breaching. Towboat emissions for the Existing Conditions alternative are estimated for projected bushel-miles and the EWITS emission factors. The emission estimates are presented in Table 4-3.

Table 4-3. Unadjusted Towboat Emissions for Alternative 1—Existing Conditions

		Pollutant				
	Units	**CO**	**VOC**	**NO_x**	**PM_{10}**	**SO_2**
Emission factors	(lbs/ton-mile)	0.000156	0.000051	0.00114	0.000024	0.000205
Emissions	(lbs)	181,989	60,663	1,337,777	28,735	239,459
	(TPY)	91.0	30.3	668.9	14.4	119.7
	(MTY)	82.5	27.5	606.8	13.0	108.6

The Transportation Analysis estimated barge bushel-miles for the 2007 grain harvest shipped on the Snake and Columbia rivers. As with the EWITS-derived emission estimates, these emissions were doubled to account for barge return trips and increased by 13 percent to account for other commodities. Dam Breaching alternative towboat emissions, adjusted for return trips and all commodities, are as follows:

Pollutant	CO	VOC	NO_x	PM_{10}	SO_2
TPY	209	70	1,538	33	275

The emissions estimated from the EWITS and Transportation Studies employ different input data, modeling approaches, and objectives, and produce different values. Because both studies include uncertainty, the emission estimates produced from the two studies were averaged. Transportation-related emissions for the Existing Conditions alternative are as follows:

Pollutant	CO	VOC	NO_x	PM_{10}	SO_2
TPY	235	285	1,705	52	266

4.1.2.3 Transportation-Related Air Quality Concentrations

Air pollutant concentrations are predicted for locations along the Snake River and heavily affected eastern Washington roads. Methodologies and input data for the predictions are presented in Chapter 3. The predicted concentrations are presented below.

Predicted Ambient Concentrations Resulting from Towboat Emissions

Emissions from towboats navigating upriver and downriver through the Ice Harbor locks were modeled using CALINE3. Meteorological input data were designed to produce the maximum

possible concentrations. The maximum concentrations are located on the Snake River shoreline. The maximum predicted concentrations, for the sum of the up- and down-river contributions, are presented in Table 4-4.

Emissions from six moored towboats were modeled using SCREEN3. Predicted annual average concentrations assume that the Ice Harbor dam experiences 45 days of fog per year. SCREEN3 determines the meteorological conditions that will produce the maximum concentrations, located on the Snake River shoreline. The maximum predicted concentrations are presented in Table 4-4.

Table 4-4. Predicted Concentrations Resulting from Towboat Emissions

Averaging	Predicted Concentrations ($\mu g/m^3$)			
Period	CO (ppmv)	NO_2 (ppmv)	PM_{10} ($\mu g/m^2$)	SO_2 (ppmv)
Concentrations Resulting from Navigating Towboats				
1-hour	0.00039			0.00022
3-hour				0.00020
8-hour	0.00027			
24-hour			0.028	0.00009
Annual		0.00014	0.006	0.00002
Concentrations Resulting from Moored Towboats				
1-hour	0.903			0.232
3-hour				0.209
8-hour	0.632			
24-hour			36.8	0.093
Annual		0.024	0.91	0.003

Maximum concentrations resulting from navigating and moored towboats may combine at a single onshore location. The combined concentrations, expressed as a percent of the AAQS (see Table 2-1), are presented in Table 4-5. All predicted concentrations are less than the AAQS.

Table 4-5. Towboat Concentrations as a Percent of the Ambient Air Quality Standards

Averaging	Predicted Concentrations (Percent of AAQS)			
Period	CO	NO_2	PM_{10}	SO_2
1-hour	3			93
3-hour				42
8-hour	7			
24-hour			25	94
Annual		45	2	11

Predicted Ambient Concentrations Resulting from Vehicle Emissions

Vehicle emissions for the US 395 and SR 260 intersection were estimated using EPA's MOBILE5 model for current traffic volumes and a fleet of vehicles in 2010. The US 395 and SR 260 intersection was modeled using CAL3QHC and 8 years of Spokane hourly meteorological data. Maximum concentrations for the Existing Conditions alternative, predicted at receptors located 30 feet from the roadways, are presented in Table 4-6. The predicted concentrations in Table 4-6 are also expressed as a percent of the AAQS. All predicted concentrations are less than the AAQS.

Table 4-6. Predicted Highway Concentrations

Period	Predicted Concentrations			
	CO (ppmv)	NO_2 (ppmv)	PM_{10} ($\mu g/m^3$)	SO_2 (ppmv)
Predicted Concentrations				
1-hour	0.50			0.0073
3-hour				0.0065
8-hour	0.21			
24-hour			4.70	0.0018
Annual		0.013	1.65	0.0006
	CO	**NO_2**	**PM_{10}**	**SO_2**
Concentration as a Percent of the AAQS				
1-hour	1			3
3-hour				1
8-hour	2			
24-hour			3	2
Annual		25	3	3

4.1.3 Windblown Fugitive Dust

For the Existing Conditions alternative, the four lower Snake River reservoirs would remain and there would be no fugitive emissions from exposed reservoir sediments.

The air quality environment of eastern Washington is dominated by naturally occurring fugitive dust generated during windstorms that take place primarily from September through November. The CP^3 program estimated total PM_{10} emissions during four storms from 1990 through 1993. The sources of fugitive dust were from rangeland; dry agricultural land, including fallow lands and land with crop residue; and irrigated agricultural land. The emissions estimates, using two different emission factor algorithms, in tons, are as follows:

Storm Date	Total Emissions by Emission Factor Algorithms (tons)		Emitting Area
	CP^3	Gillette	
November 23, 1990	11,905	24,992	5,288,528
October 21, 1991	19,070	186,621	2,391,476
September 11, 1993	234,792	127,868	2,033,916
November 3, 1993	20,834	89,177	2,881,732

These storms represent extreme events. According to the database used to generate the windrose figures presented in Section 2, eastern Washington may experience an average of about 10 windstorm events of varying intensity each year from September through November.

The CP^3 emissions and concentration modeling effort calibrated the predicted concentrations with measured concentrations in eastern Washington (Table 4-7). Measured PM_{10} concentrations often exceed the 24-hour AAQS during these storm events. Plots of the predicted concentrations, reproduced from Claiborn et al. (1998), are presented in Annex C.

Table 4-7. Measured PM_{10} Concentrations during Eastern Washington Storm Events

Date	Average Wind Speed at Othello, Washington (m/sec)	Measured 24-Hour PM_{10} Concentration ($\mu g/m^3$) Spokane	Kennewick
November 23, 1990	9.4	251	126
October 21, 1991	4.0	351	1,035
September 12, 1992	5.8	803	58
September 14, 1992	5.8	321	46
October 8, 1992	3.6	185	49
September 11, 1993	4.9	300	118
November 3, 1993	6.7	207	1,166

Source: Claiborn et al., 1998.

4.1.4 Power Plant Emissions

Power generation by the four lower Snake River reservoirs would continue under this alternative, eliminating the need for replacement power. However, the demand for energy will continue to increase, resulting in a need for additional generating capacity, regardless of the status of the lower Snake River dams. The Technical Report on Hydropower Costs and Benefits (DREW, 1999a) evaluated the need for additional generating capacity and included additional natural gas-fired, combined-cycle plants in their projections. Emission estimates for coal-, fuel oil-, and natural gas-fired generating units, produced by the PROSYM model for the A1 case (Existing Conditions alternative) are presented in Table 4-8. The CO_2, NO_x, and SO_2 emissions predicted by PROSYM were used to estimate emissions for other criteria and hazardous air pollutants presented in Table 4-8.

Emissions from generating units throughout the WSCC, representative of the Existing Conditions alternative, for 2010 for all fuel types in thousands of tons are as follows:

Pollutant	CO	CO_2	NO_x	PM_{10}	SO_2	VOC	Benzene	Formaldehyde
1000 TPY	404	414,234	58	49	457	1	0.004	0.04

In the 7-year period from 1990 to 1997, U.S. CO_2 emissions increased from 4,929 to 5,457 million metric tons (5,433 to 6,014 million tons). This represents an increase of about 11 percent (EPA, 1999). If GHG emission rates continue to increase at the same rate, national CO_2 emissions in 2011 would be about 6,683 million metric tons (7,367 million tons). The 2010 power plant CO_2 emissions presented above may be compared to the projected national emissions. Western U.S. electric utility CO_2 emissions represent 5.6 percent of the national CO_2 emissions.

4.2 Major System Improvements Alternative

Structural enhancements to improve downstream migration of juvenile salmon would be added to each of the four lower Snake River projects under this alternative. The proposed enhancements consist of various surface bypass collector (SBC) systems. Details on the system enhancement alternatives and designs are provided in the Existing Conditions and Major System Improvements Engineering Appendix (Appendix E).

Table 4-8. Power Generating Emissions for Existing Conditions Alternative

Generation Resource	Emissions (thousands of tons)							
	CO	CO_2 1/	NO_x 1/	PM_{10}	SO_2 1/	VOC	Benzene	Formaldehyde
Coal								
Arizona/New Mexico	76	77,952	16	19	173	0.2	0.0013	0.0002
Canada	45	45,916	8	8	75	0.1	0.0007	0.0001
Northwest	12	12,147	2	4	40	0.03	0.0002	0.00003
Rocky Mountains	117	119,825	24	18	165	0.3	0.0019	0.0003
Fuel Oil								
FO #2	0.3	1,142	0.04	0.004	0.4	0.001	-	0.0001
FO #6	0.01	37	0.003	0.0003	0.1	0.0001	-	0.00001
Natural Gas								
Alberta	0.2	213	0.003	0.0003	0.02	0.0002	-	0.00002
Arizona/New Mexico	5	5,000	1	0.07	0.03	0.04	-	0.004
British Columbia	0.4	358	0.004	0.0004	0.003	0.0002	-	0.00002
Future Combined Cycle	87	88,258	2	0.2	1	0.1	-	0.01
Northern California	11	10,947	1	0.08	0.1	0.05	-	0.005
PG&E IPPs	13	12,961	1	0.1	1	0.06	-	0.006
Pacific Northwest	9	8,856	0.2	0.02	0.1	0.009	-	0.001
Rocky Mountains	3	3,200	0.5	0.04	0.02	0.02	-	0.003
Rocky Mountains/Colorado	2	1,924	0.1	0.01	0.01	0.006	-	0.001
Southern California	13	12,987	1	0.06	0.1	0.03	-	0.004
SCE IPPs	12	11,758	1	0.1	3	0.06	-	0.007
SDG&E IPPs	1	753	0.1	0.01	0.01	0.004	-	0.0004
Total System Emissions	**404**	**414,234**	**57.8**	**49.3**	**457.4**	**1**	**0.004**	**0.04**

1/ Source: DREW, 1999a.

4.2.1 Construction-Related Fugitive Emissions

System enhancements would consist of SBC systems combined with structural modifications at each facility. The SBC structures, consisting mostly of channels, may be built from components constructed offsite, or may be built in-place. Therefore, construction-related air emissions for this alternative would be very small and would include particulate matter emissions from mixer trucks and haul roads.

For comparison of alternatives, this analysis has conservatively assumed a total of 1 MT (1.1 ton) of PM_{10} emissions for all four structural enhancement projects. Furthermore, construction is assumed to take place in one year.

4.2.2 Loss of Barge Transportation

Barge transportation on the navigable portions of the Columbia and Snake rivers would continue with this alternative. Generally, transportation air emissions would be identical to the emission estimates presented for the Existing Conditions alternative (Section 4.1.2). With this alternative, there may be emissions increases related to operation of towboats for fish barging (Appendices A, B, and E). The increases result from loading methods and are minimal (less than 1 ton per year for all regulated air pollutants).

4.2.3 Windblown Fugitive Dust

For this alternative, the four lower Snake River reservoirs would remain in their present condition. There would be no fugitive emissions from exposed reservoir sediments. Fugitive dust emissions from agricultural lands, as part the existing environment, were described in Section 4.1.3. The same emission conditions are applicable to the Major System Improvements alternative.

4.2.4 Power Plant Emissions

Power generation by the four lower Snake River reservoirs would continue, eliminating the need for replacement power and associated air emissions. However, the demand for energy will continue to increase, resulting in the need for additional generating capacity. The Power System Analysis evaluated the need for additional generating capacity and included additional natural gas-fired combined-cycle power plants in their projections (DREW, 1999a). Construction of these power plants will continue for the Existing Conditions, Major System Improvements, and Dam Breaching alternatives. Emissions for the Major System Improvements alternative are very similar to those for the Existing Conditions alternative. Differences between these alternatives were not quantified.

4.3 Dam Breaching Alternative

Air quality issues associated with the Dam Breaching alternative include impacts from demolition-related emissions, loss of barge transportation, windblown fugitive dust from exposed dry sediments, and emissions from thermal power plants replacing hydropower.

Air quality impacts associated with drawdown may be more extensive than presented in this section. The primary aluminum industry is an example. The availability of inexpensive electricity encouraged a primary aluminum industry in the Pacific Northwest, where alumina is electrically reduced to elemental aluminum. The process uses carbon anodes that are continuously depleted by the reaction. All or most of the carbon used in the production process is emitted as CO or CO_2. In

1996, CO emissions equal to 26,082 metric tons (28,751 tons) were reported by an aluminum plant, located north of Spokane in Mead, Washington (EPA, 2000b). Without a source of inexpensive electricity, these sources may leave the region. Other indirect affects may include, but are not limited to, the following:

- changes in agricultural fugitive dust emissions as farming practices shift from irrigated to dryland farming
- changes in pesticide levels emitted along with agricultural fugitive dust emissions
- changes in industrial emissions associated with changes in energy and transportation resources
- changes in transportation emissions following modification of the mix of eastern Washington industries after dam breaching
- changes in home heating practices and related emissions.

These impacts are not evaluated in this analysis.

4.3.1 Demolition-Related Fugitive Emissions

Deconstruction of the four lower Snake River dams will require a number of steps, described in the Natural River Drawdown Engineering Appendix (Appendix D). The steps required to deconstruct each dam include lowering the reservoir, excavating embankments, removing cofferdams, routing the river around concrete structures, constructing levees as necessary, riprap production, and hauling and stockpiling for bank protection of existing railroad embankments. These activities would produce fugitive dust emissions. PM_{10} emission sources are material handling activities such as hauling, dumping, bulldozing, and grading.

4.3.1.1 Estimated Demolition Emissions

Embankment and Abutment Excavation Emission Estimates

The objective of this analysis is to provide general emission estimates for the purpose of comparing the alternatives. Because many of the details, such as the number, weight, and capacity of haul trucks, length of haul roads, rate of excavation, and location of stockpiles, can only be approximated, only a preliminary analysis of fugitive emissions is possible at this time. Estimates of the equipment hours required for the project are available and are used to estimate bulldozer and grader emissions. PM_{10} emissions from batch dropping and hauling activities are estimated from the volume of material excavated from each facility. The methodology for the emission calculations was presented in Section 3. Excavation quantities and equipment operating hours, obtained from the Natural River Drawdown Engineering Appendix (Appendix D), are presented in Tables 3-3 and 3-4, respectively. These data were used in the emission calculations.

Fugitive PM_{10} emissions were calculated from emission factor expressions, default data values, operating hours, and excavation volumes presented in Section 3. It is assumed that mitigation measures (for example, watering) will achieve a 50 percent reduction in haul road emissions. The estimated PM_{10} emissions are presented by dam and construction activity in Table 4-9.

Table 4-9. Estimated Deconstruction PM_{10} Emissions

	Emissions (tons per year)			
Operation	**Ice Harbor**	**Lower Monumental**	**Little Goose**	**Lower Granite**
Bulldozer	3.54	2.61	2.60	3.12
Hauling	150.5	183.7	67.7	63.4
Dumping	0.9	1.1	0.4	0.4
Grading	46.5	34.3	31.5	41.0
Total	**201.5**	**221.7**	**102.1**	**108.2**

Quarry Excavation Emission Estimates

Drawdown of the four lower Snake River reservoirs will require that road and railroad embankments be protected by construction of drainage structures and diversion levees. In addition, steps must be taken to repair embankments that slump following drawdown. Preliminary plans for these activities are presented in the Natural River Drawdown Engineering Appendix (Appendix D). Production of riprap for these modifications and repairs will require pre-drawdown quarry excavations that will produce fugitive dust emissions. PM_{10} emission sources include material handling activities such as rock screening, rock crushing, hauling, and dumping.

This analysis provides general emission estimates for quarry activities. Many details, such as the number, weight, and capacity of haul trucks, length of haul roads, rate of excavation, and volume and rate of material processed, can only be approximated at this time. PM_{10} emissions from screening, crushing, hauling, and dumping are all estimated from the volume of material required from each quarry. The methodology for the emission calculations was presented in Section 3. Quarried rock volumes, obtained from the Natural River Drawdown Engineering Appendix (Appendix D), are presented in Table 3-5.

Fugitive PM_{10} emissions were calculated from emission factor expressions, default data values, and quarried volumes presented in Section 3. It is assumed that mitigation measures (for example, watering) will achieve a 50 percent reduction in haul road emissions. Quarry activities will occur over the course of 3 years. The estimated PM_{10} emissions are presented in Table 4-10 by quarry and activity.

Table 4-10. Estimated Emissions from Quarry Activities

		Estimated Emissions (TPY)	
Activity	**Quarry 1**	**Quarry 2**	**Quarry 3**
Screening rock	19	51	29
Crushing rock	0	0	0
Hauling	80	215	152
Dumping	2	4	3
Total	**102**	**271**	**187**

Combining the excavation and quarry emissions provides an estimate of PM_{10} emissions by reservoir. Emissions associated with Quarry 2 are evenly split between Lower Monumental and Little Goose. The combined emissions are as follows:

	Ice Harbor	Lower Monumental	Little Goose	Lower Granite
TPY	304	357	237	295

4.3.1.2 Predicted Demolition Concentrations

Haul road and stockpile emissions were modeled with ISCST3 and worst case meteorology. Predicted 24-hour PM_{10} concentrations downwind of the sources are presented on Figures 4-1 and 4-2 for the excavation and quarry haul roads, respectively. The 24-hour AAQS concentration (150 $\mu g/m^3$) is indicated on the figures as a heavy contour line. The concentration appropriate for comparison to the AAQS is the maximum concentration in areas of public access. A contour plot of the predicted 24-hour concentration is presented because public restriction to the demolition site has not been established. Future modeling will indicate levels of mitigation to minimize dust emissions and areas of restricted public access. For example, it is possible to water spray the haul roads frequently to keep the road surface moist, thereby reducing fugitive emissions by about 90 percent. Alternatively, the haul roads may be paved or replaced with covered conveyors.

According to the excavation plan (Appendix D, Annex B), the demolition schedule is short (55 days). Annual average PM_{10} concentrations resulting from deconstruction fugitive emissions would be less than the annual AAQS (50 $\mu g/m^3$).

The Wallula PM_{10} nonattainment area is only 18 km (11 miles) south-southeast of the Ice Harbor Dam. Although the predominant wind directions at Ice Harbor follow the orientation of the Snake River, deconstruction fugitive emissions could reach Wallula. Deconstruction emissions were modeled with 6 years of Yakima meteorological data. Predicted 24-hour PM_{10} concentrations at Wallula are less than the 5 $\mu g/m^3$ significance level (Figure 4-3). The slight increase in concentration at about 4 km from the site represents the distance at which contributions from the various sources combine to form a maximum.

Additional analysis is required before demolition may begin. Additional data requirements include the following:

- A detailed inventory of sources of fugitive emissions and the schedule showing when each source will be active
- The number of trucks needed to transport the excavated material and the empty and full weight of each truck type used
- The fugitive dust mitigation plan, including water spraying, paving, and conveyors
- The site boundary to define areas restricted to the public
- Site-specific variables used in the emissions calculations, including soil moisture content and road silt content
- Site-specific meteorological data, or data sufficient to define the relationship between onsite wind conditions and a long-term database.

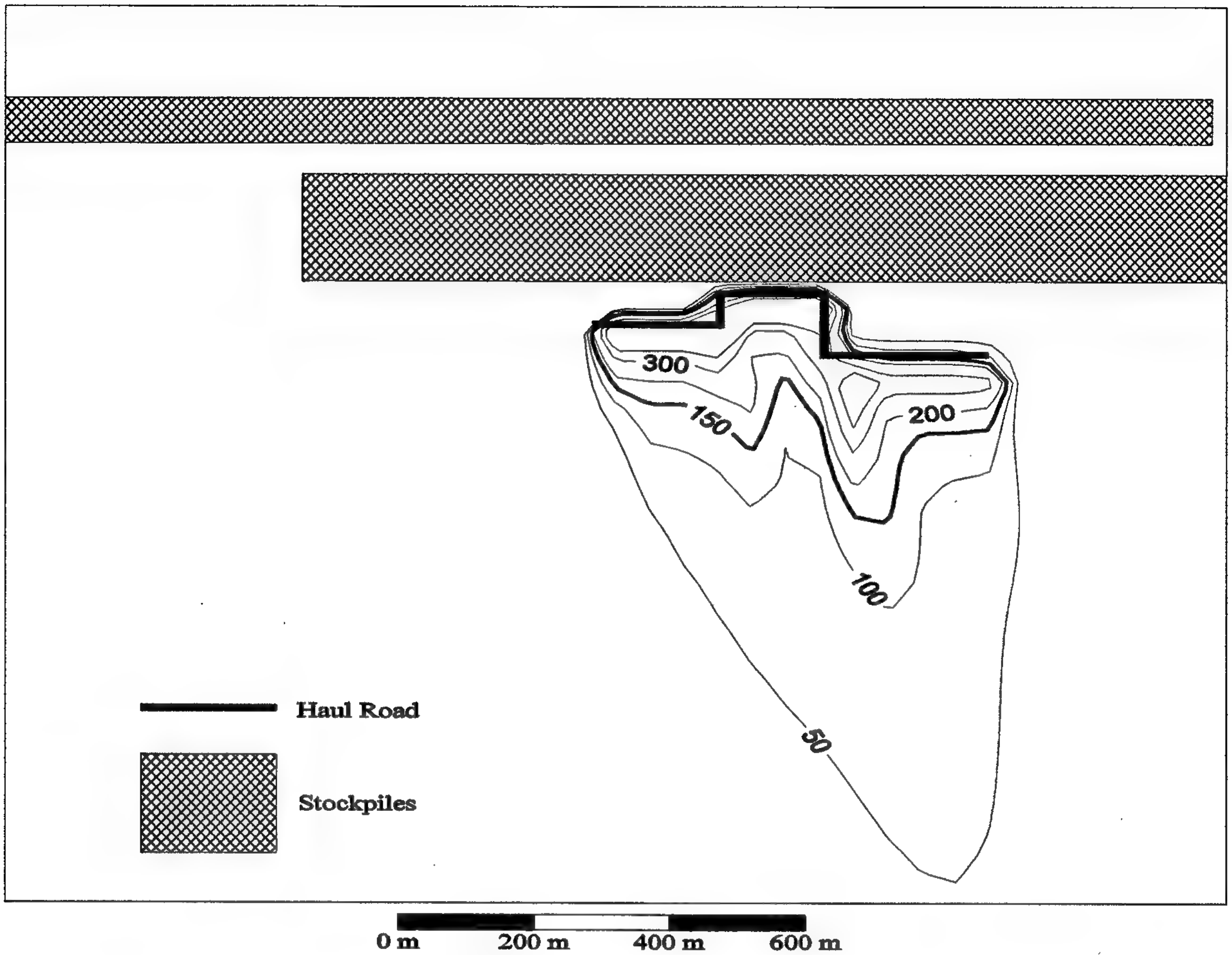

Figure 4-1. Predicted 24-Hour PM_{10} Concentrations from Excavations at Lower Monumental Dam

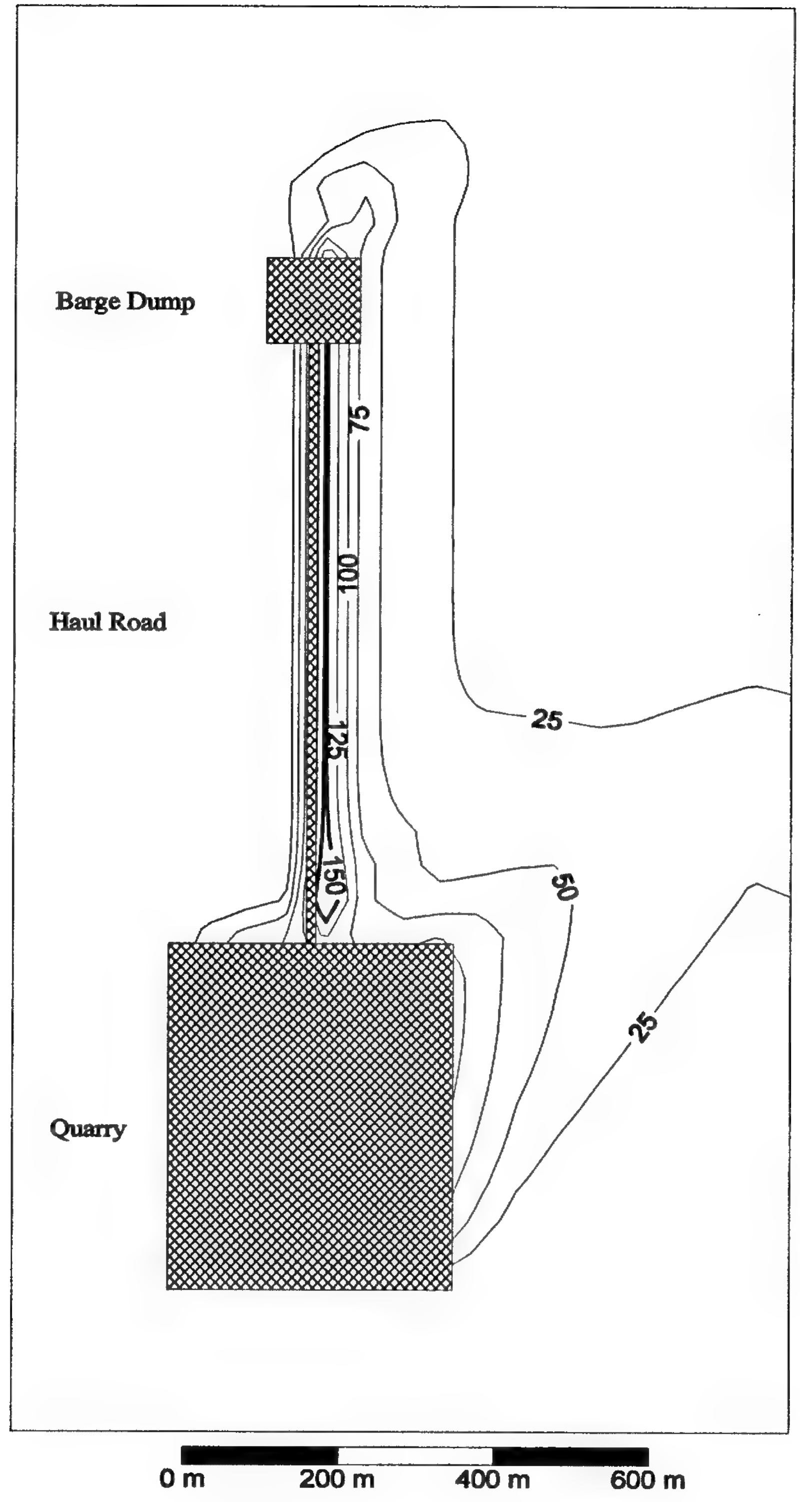

Figure 4-2. Predicted 24-Hour PM_{10} Concentrations from Quarry Operations

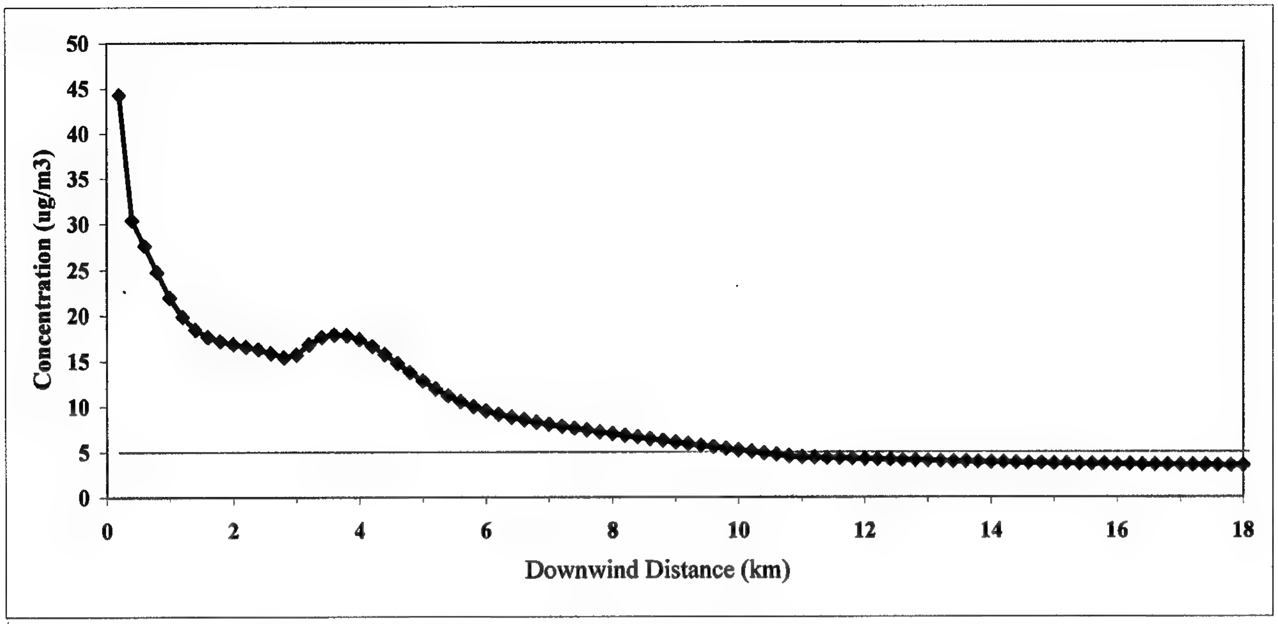

Figure 4-3. Predicted 24-Hour PM_{10} Concentrations with Distance South of the Ice Harbor Dam

Deconstruction of the lower Snake River dams may be compared to other large demolition projects. The Elwha and Glines Canyon dams in Olympic National Park are slated for demolition. Removal of both dams would generate 200,000 yd^3 of concrete, rock, and earth fill (National Park Service, 1996). Another 50,000 yd^3 of concrete and compact rock fill would be used to backfill the spillway outlet channel and restore natural contours. The Lower Monumental excavation would generate 30 times more material than demolition of both the Elwha and Glines Canyon dams. The two projects are compared as follows:

	Elwha and Glines Canyon	Lower Monumental
Excavation volume (m^3)	191,000	5,716,340
Period of excavation	2 years	55 days
Haul road PM_{10} emissions (tons)	112	171
Predicted 24-hour PM_{10} concentration ($\mu g/m^3$)	144	150
Distance to predicted concentration (m)	100	55 and 134

4.3.2 Loss of Barge Transportation

Barge transportation on the navigable portions of the Snake River would cease under the Dam Breaching alternative. Emission estimates for this alternative are compared to estimates for the Existing Conditions alternative. Emissions have been estimated from two data sources. The EWITS and Transportation Analysis studies use different methods to estimate transportation-related impacts for the Dam Breaching alternative. Methods used to estimate air emissions were presented in Section 3.

4.3.2.1 Eastern Washington Intermodal Transportation Study

Transportation of wheat and barley from eastern Washington to Portland was investigated by EWITS (Lee and Casavant, 1998). Two cases were modeled by EWITS: the 1994 grain harvest with and without the availability of Snake River barge transportation. Transportation-related emissions for the Existing Conditions alternative for wheat and barley and extrapolated to other commodities were presented in Section 4.1.2. Emission estimates presented below are representative of the Dam Breaching alternative.

Grain normally shipped to Snake River ports would be trucked to elevators with rail loading facilities. Production areas away from the Snake River would truck grain to elevators adjacent to railroads. A sizable amount of grain would still be trucked directly from production areas to river ports at or below the Tri-Cities area. Elevator to river port shipments would decrease by 21 percent, while elevator to Portland rail shipments would increase by the same amount. About 28 million bushels of wheat would switch from barges to trains. About 62 percent of the barley harvest is trucked to non-Snake River ports and then barged to Portland. The volume of barley barged to Portland decreases only slightly without the Snake River.

Without the Snake River, truck traffic would be concentrated on roads that lead to and from the Tri-Cities, especially US 395. The local and rural roads east of Pasco would also receive much of the increased truck traffic.

The modeled wheat and barley ton-miles are presented in Table 3-9 for the Dam Breaching alternative. Comparison with Table 3-8 indicates that train and truck ton-miles will increase from 40 to 87 percent. Air emissions for wheat and barley transportation modes, unadjusted for return trips and other commodities, are presented in Table 4-11.

Table 4-11. Unadjusted Wheat and Barley Transportation-Related Emissions without the Snake River Barge Transportation

		Emissions (tons)				
Mode	**Commodity**	**CO**	**VOC**	**NO_x**	**PM_{10}**	**SO_2**
Barge	Wheat	38.3	12.8	281.6	6.0	50.4
	Barley	4.3	1.4	31.2	0.67	5.6
Train	Wheat	45.7	15.2	357.3	8.7	26.1
	Barley	0.016	0.005	0.122	0.003	0.009
Truck	Wheat	81.0	20.0	184.8	13.7	5.1
	Barley	19.8	4.9	45.1	3.4	1.3
Total		**189.1**	**54.3**	**900.1**	**32.5**	**88.5**

Source: Lee and Casavant, 1998.

The emission estimates presented in Table 4-11 are for wheat and barley. Emission estimates that account for other commodities and return trips are derived in the same manner as presented in Section 4.1.2. Total transportation-related emissions are as follows:

Pollutant	CO	VOC	NO_x	PM_{10}	SO_2
TPY	259	611	1,932	82	208

The change in transportation-related emissions is the difference between the emissions for the Dam Breaching and Existing Conditions alternatives and is estimated from the EWITs data as follows:

Pollutant	CO	VOC	NO_x	PM_{10}	SO_2
TPY	(1)	111	60	11	(48)

Trucks are used to haul grain from producers and intermediate storage locations to elevators adjacent to railroads and waterways. The movement of products over eastern Washington highways was simulated as part of EWITS GIS/GAMS modeling effort (Jessup, Ellis, and Casavant, 1997). Maps showing wheat and barley highway flows for the Dam Breaching alternative are reproduced in Annex B.

4.3.2.2 The Transportation Analysis

Changes in barge, train, and truck bushel-miles are estimated as part of the Transportation Analysis. These estimates represent the change in bushel-miles required to bring the 2007 wheat and grain harvest to market following drawdown. With the Dam Breaching alternative, grain quantities normally trucked to river ports would be trucked to elevators located on rail lines or to the Tri-Cities area for barge shipment. In Idaho, the truck-miles decrease, indicating that rail-based grain elevators are closer than Lewiston. The emission factors from Lee and Casavant (1998) are used in this part of the analysis. The emission estimates are doubled to account for containers that return empty and are increased by 13 percent to include other commodities. Barge, train, and truck emissions, presented in Table 4-12, account for all commodities and vehicle return trips. The changes in total transportation-related emissions are as follows:

Pollutant	CO	VOC	NO_X	PM_{10}	SO_2
TPY	(14)	86	47	11	(87)

The NO_x and SO_2 emission factors are relatively large for towboats. Large decreases in barge bushel-miles translate into large decreases in NO_x and SO_2 emissions. The high increase in train bushel-miles, combined with the relatively high locomotive NO_x emission factors, offsets the reduction in towboat NO_x emissions. The truck VOC emission factor, combined with higher truck energy requirements, results in the greatest increase in VOC emissions.

Table 4-12. Change in Transportation-Related Emissions Following Dam Breaching

Transportation	Emissions (tons)				
Mode	**CO**	**VOC**	**NO_x**	**PM_{10}**	**SO_2**
Barge	(107)	(36)	(787)	(17)	(141)
Train	83	31	794	51	51
Truck	10	91	40	3	3
Total	**(14)**	**86**	**47**	**11**	**(87)**

Two data sources are used to estimate transportation-related emissions that are a consequence of the Dam Breaching alternative. The EWITS and Transportation Analysis data result in different emission estimates. The EWITS data suggest that NO_x, PM_{10}, and VOC emissions would increase, CO emissions would remain about the same, and SO_2 emissions would decrease. The Transportation Analysis data indicate that NO_x, PM_{10}, and VOC emissions would increase and CO and SO_2 emissions would decrease. The change in transportation-related emissions, averaged from the EWITS and Transportation Analysis results, is as follows:

Pollutant	CO	VOC	NO_x	PM_{10}	SO_2
TPY	(8)	98	54	11	(68)

The estimated change in transportation-related emissions may be used to estimate the change in GHG and HAP emissions. Emission factors for these pollutants, as a percent of other pollutants, were presented in Section 3.2. CO_2 emissions are projected to decrease by about 700 tons per year. Benzene and formaldehyde emissions are estimated to increase by about 500 and 600 pounds, respectively.

All transportation-related emissions will continue to decline in the future as fuel efficiencies improve and as national emission standards become effective if traffic volumes remain relatively constant. Emissions standards for locomotives were scheduled to take effect in 2000. Emission standards for compression-ignition marine engines are proposed to become effective in 2004. The first phase of a proposed strategy to reduce emissions from heavy-duty vehicles will become effective in 2004. These initiatives were not considered in the emission estimates.

4.3.2.3 Estimated Vehicle Distribution Resulting from Dam Breaching

The Dam Breaching alternative would change the distribution of vehicles carrying harvested grain. With drawdown, truck traffic would decrease on highways leading to river ports and would increase on roads to rail-based elevators and the Tri-Cities area. Modeling estimated the number of grain bushels on eastern Washington roads with and without drawdown (Lee and Casavant, 1998; Jessup, Ellis, and Casavant, 1997). Predicted grain quantities are used to estimate the change in the number of trucks on selected highways and are combined with WSDOT traffic counts.

Jessup, Ellis, and Casavant (1997) graphically depicted the number of bushels of grain, as a range of values, on eastern Washington roads (Annex B). The upper range, in millions of bushels, was

converted to truck counts at selected locations. The grain volumes and truck counts are presented in Table 4-13. The estimated number of trucks hauling grain has been doubled to account for return trips.

Table 4-13. Change in the Number of Trucks Following Dam Breaching

		With Snake River		Without Snake River		Number of Trucks Per Day			
Highway	Inter-section	Millions of Bushels of Grain	Total No. of Trucks[1/]	Millions of Bushels of Grain	Total No. of Trucks[1/]	Current	Change w/ Dam Breaching	Projected	Percent Change
US 395	SR 26	6	6,923	59	68,083	2,480	1,003	3,483	40
	SR 260	6	6,923	59	68,198	2,160	1,005	3,165	47
SR 127	SR 26	6	6,923	3	3,462	290	(57)	233	(20)
SR 195	SR 272	19	21,923	7	8,077	1,920	(227)	1,693	(12)
SR 26	SR 395	6	6,923	27	31,385	375	401	776	107
	SR 195	3	3,462	19	21,923	575	303	878	53
SR 260	West of 395	6	6,923	2	2,308	884	(76)	808	(9)
	East of 395	3	3,462	2	2,308	195	(19)	176	(10)

[1/] Total number of trucks per grain-harvesting season.

The greatest increase in truck counts would take place along US 395 and SR 26 just before US 395. Truck traffic along highways used to haul grain to river ports (SR 127 and SR 195) would decrease.

4.3.2.4 Traffic-Related Air Pollutant Concentrations

Vehicle emissions for the US 395/SR 260 intersection were estimated by EPA's MOBILE5 model for current traffic volumes plus 1,005 trucks per day. The EWITS modeling indicated that total wheat and barley truck traffic on SR 260 will not change appreciably with dam breaching. The SR 260 links in the highway modeling used pre-breaching emission factors. The increases in traffic on US 395, 1,005 trucks per day, are for the September through December period. The intersection was modeled using CAL3QHC and 8 years of Spokane hourly meteorological data. Increases in maximum concentrations, predicted at receptors adjacent to the roadway, represent impacts associated with the Dam Breaching alternative (Table 4-14). The predicted concentrations in Table 4-14 are also expressed as a percent of the AAQS and may be compared to the pre-breaching concentrations presented in Table 4-6. All predicted concentrations are lower than the AAQS. Following drawdown, increases in concentrations resulting from traffic emissions will be small, less than 2 percent of the AAQS.

Table 4-14. Predicted Highway Concentrations Following Drawdown

Period	CO (ppmv)	NO_2 (ppmv)	PM_{10} (μg/m^3)	SO_2 (ppmv)
	Predicted Concentrations			
Predicted Concentrations				
1-hour	0.50			0.0085
3-hour				0.0077
8-hour	0.36			
24-hour			7.22	0.0028
Annual		0.0178	1.95	0.0007
	CO	**NO_2**	**PM_{10}**	**SO_2**
Concentration as a Percent of the AAQS				
1-hour	1			3
3-hour				2
8-hour	4			
24-hour			5	3
Annual		33	4	4

The model estimated the changes in emissions and ambient concentrations associated with traffic impacts resulting from drawdown. This analysis assumed the following:

- The maximum daily traffic volumes were modeled, and it was assumed that traffic volumes do not vary throughout the year.
- The maximum daily traffic volumes and cold weather emission factors were modeled with a full year of meteorological data to produce the average annual concentrations.
- The traffic mix will not change from 1999 to 2010.
- The traffic mix is based on the percent of trucks as indicated in the WSDOT traffic data.
- Traffic lights will be added to the intersection of the on and off ramps with SR 260 before 2010.

The preliminary analysis above indicates that the increases in emissions and concentrations associated with drawdown are small.

If the Dam Breaching alternative is selected, additional analysis of traffic emissions may be required. The steps required to conduct the analysis are as follows:

- Select several intersections that will be heavily affected by drawdown (bushel-mile modeling for the eastern Washington grain harvest conducted for the transportation economic analysis will assist with selecting intersections). Include examples of intersections affected in positive and negative manners.
- Measure the lengths and widths of all roadway segments of the selected intersections.
- Install roadway counters to determine total traffic volumes and periods of peak volumes.
- Conduct a traffic survey to count vehicles by the MOBILE5 vehicle categories (light duty gasoline vehicles, light duty gasoline trucks, light duty diesel trucks, motorcycles, and so forth).

- Determine the cycle time for signalized intersections or intersections that may become signalized.
- Project the traffic volumes for an appropriate year, with and without drawdown.
- Estimate vehicle emissions using the latest version of MOBILE5 or an equivalent mobile source emission model.
- Model the intersections, with and without drawdown, using CAL3QHC, taking advantage of the model's ability to vary emissions by time.

4.3.3 Windblown Fugitive Dust

As drawdown proceeds, the reservoir sediments would dry and become subject to wind erosion. According to the Natural River Drawdown Engineering (Appendix D) Reservoir Revegetation Plan (Annex K), vegetation would proceed in phases:

- Initial aerial seeding done in phases during drawdown
- Drill seeding to revegetate areas where the initial seeding did not work
- Manual planting of willow and cottonwood trees
- Annual efforts to reestablish vegetation in problem or disturbed areas.

Drawdown would take place from August through October, which corresponds to the beginning of the dust storm season. Because large areas of dry sediments would be exposed to wind erosion, the total PM_{10} emissions may be large.

4.3.3.1 Windblown Fugitive Dust Emissions

This analysis estimated PM_{10} emissions using EPA methods and 1984 through 1991 wind data from Pendleton, Spokane, and Yakima. For each data source, hourly average wind speeds were converted to a value representative of 2-minute speeds just above the sediment surface. A wind speed-dependent emission factor was determined for each hour when the wind speed was greater than the threshold frictional velocity. The hourly emission factors were multiplied by the area of each of the four reservoirs, a particle size multiplier, and a reduction factor to account for mitigation. The hourly emissions were added to form an annual emission estimate for each year of data, each reservoir, and each of the three data sources (Pendleton, Spokane, and Yakima). The three annual emission estimates (Pendleton, Spokane, and Yakima) were averaged. Emissions for the four reservoirs were added to form a total average PM_{10} emission rate.

The estimated annual PM_{10} emissions for the three data sources and the four reservoirs are presented in Table 4-15. The annual average PM_{10} emissions by reservoir (with vegetation cover) are as follows:

	Ice Harbor	Lower Monumental	Little Goose	Lower Granite
TPY	1,555	1,224	1,861	1,652

The dry reservoir emission estimates overestimate the total emissions. Individual windstorms affect only a portion of the lower Snake River region, whereas the emission estimates assume that all reservoirs are subject to the same wind conditions. It is interesting to note that the threshold

frictional velocities of dryland soils with residue, rangelands, some dryland fallow soils, and some irrigated soils are higher than the dry reservoir sediments.

The meteorological database may be used to determine the expected number of windstorms that could produce fugitive emissions and the relative magnitude of the emissions during each storm. The frequency of emissions, in 90.7-metric ton (in 100-ton) increments, was determined for all four reservoirs by meteorological data source. The data indicate that nearly all storms produced total PM_{10} emissions of less than about 181 metric tons (200 tons) per event (Figure 4-4) from all four reservoirs, which is equivalent to about 5.44 kg per hectare (0.006 ton per acre).

Table 4-15. Annual Estimated Windblown PM_{10} Emissions

	Emissions (tons)			
Year	**Ice Harbor**	**Lower Monumental**	**Little Goose**	**Lower Granite**
Pendleton Data				
1984		506	770	683
1985		304	463	411
1986		249	379	336
1987		369	561	498
1988		1,080	1,643	1,458
1989		457	695	617
1990		1,741	2,648	2,351
1991		1,176	1,790	1,589
Spokane Data				
1984	1,803	1,418	2,158	1,916
1985	2,017	1,587	2,415	2,144
1986	2,002	1,575	2,396	2,127
1987	1,807	1,422	2,163	1,921
1988	3,007	2,366	3,599	3,195
1989	2,857	2,248	3,420	3,036
1990	3,420	2,691	4,094	3,634
1991	1,627	1,280	1,948	1,729
Yakima Data				
1984	579	455	693	615
1985	794	625	950	844
1986	723	569	866	769
1987	447	352	535	475
1988	1,522	1,198	1,822	1,617
1990	1,134	892	1,357	1,205
1991	1,231	969	1,474	1,308

The results presented above are conservative. Field studies indicate that 3 hours of high wind speeds from the same direction are required to initiate windblown dust (Environalysis, 1996). Furthermore, winds producing fugitive dust in one region of the lower Snake River would not affect the entire river basin. The Revegetation Plan (Appendix D) calls for seeding sediments as the water recedes and restricting access to the dry reservoirs, thereby minimizing the amount of available erodible material. This analysis assumed that mitigation efforts would reduce emissions by 90 percent. Field studies at Owens Lake in California indicate a salt grass cover of 50 percent can

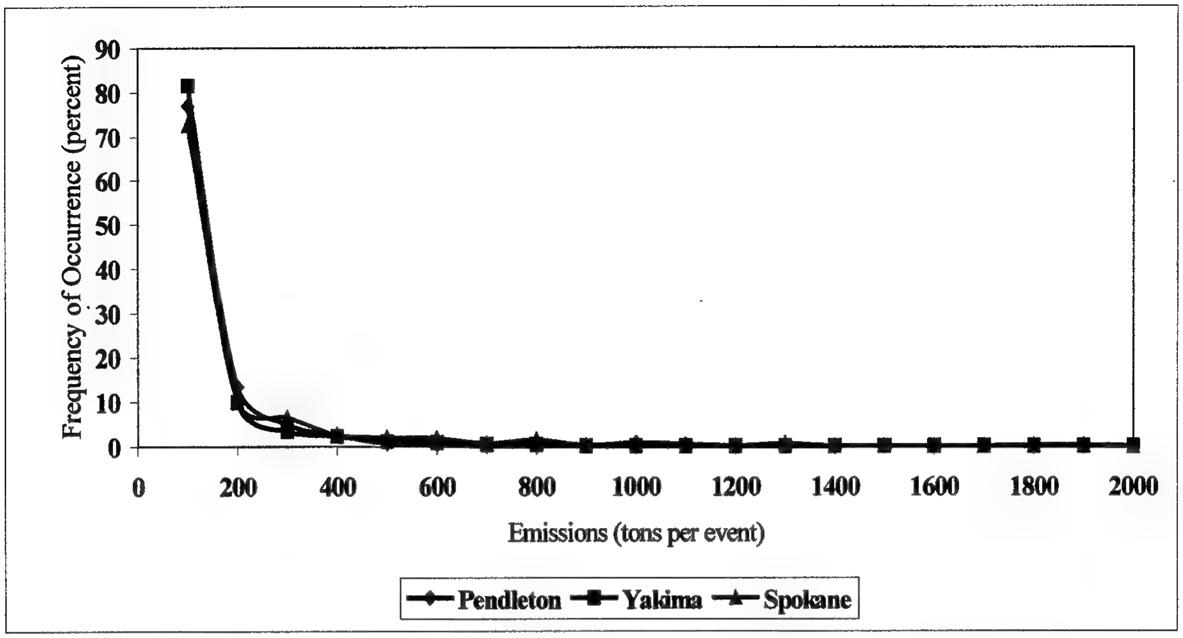

Figure 4-4. Frequency of Occurrence of Predicted Emissions for Individual Wind Events

reduce soil erosion and PM_{10} emissions by 99 percent (Great Basin Unified Air Pollution Control District, 1998). Similar reductions are expected for the dry lower Snake River reservoirs.

Rain often accompanies strong winds. This analysis did not screen out occasions of precipitation with strong winds, but it did reduce the annual emission estimates to account for the average number of days of precipitation.

The population most susceptible to windblown dust from exposed sediments would be residences along the river. Because the Snake River valley would channel the winds, residences located near river bends would be most susceptible to windblown dust.

The Owens Lake study estimated that the annual PM_{10} emissions are from 117,900 metric tons to 362,900 metric tons (130,000 to 400,000 tons) (Section 2.3.2). The Owens Lake emitting area is about 90.65 square kms (35 square miles), resulting in an annual emission rate of about 5.3 metric tons (5.8 tons) per acre. Once controls are in place, Owens Lake would emit about 0.2 tons per acre. Annual emissions from all four lower Snake River reservoirs, with mitigation measures in place, are estimated to be about 181.4 kg per hectare (0.2 tons per acre) on an annual basis.

4.3.3.2 Windblown Fugitive Dust Concentrations

Autumn storms that produce fugitive dust from the agricultural areas of eastern Washington would also generate fugitive emissions from the dry lower Snake River reservoirs. The CP^3 program modeled emissions and concentrations from several storms from 1990 to 1993. The November 1990 and October 1991 storms, modeled by CP^3, are included in the meteorological database used to generate the reservoir emission estimates. Dry reservoir emissions were estimated by the methods

described in Section 3. The CP^3 emissions (using two emission algorithms) and the reservoir emissions (using three data sources) are as follows:

	November 23, 1990		October 21, 1991	
	(tons)	(tons/acre)	(tons)	(tons/acre)
Rangeland, Dry Land, and Irrigated Land				
CP^3 emission algorithm	11,905	0.00225	19,070	0.00473
Gillette algorithm	25,022	0.00797	186,621	0.0780
Average	18,464	0.00511	102,846	0.0414
Reservoirs				
Yakima winds	877	0.0259	279	0.00823
Spokane winds	3,880	0.114	606	0.0179
Pendleton winds	0	0	274	0.00808
Average	2,379	0.0468	386	0.00866

Emissions from the reservoirs are 13 and 0.4 percent of the emissions from agricultural lands for the 1990 and 1991 storms, respectively. Both of these storms moved through eastern Washington toward the northeast. The 1990 storm completely missed the Pendleton area, indicating that individual storms may influence only part of the lower Snake River reservoir system. PM_{10} concentration plots for three storms, reproduced from Claiborn et al. (1998), are presented in Annex C. These plots indicate that surface PM_{10} concentrations in the region of the reservoirs can be very large during these windstorms.

Measured Kennewick and Spokane PM_{10} concentrations during the 1990 and 1991 storms are available and were used by CP^3 to calibrate its dispersion model. The measured 24-hour PM_{10} concentrations are as follows:

	November 23, 1990	October 21, 1991
24-hour measured PM_{10} concentrations ($\mu g/m^3$)		
Kennewick site	126	1,035
Spokane (industrial site)	-	351
Spokane (residential site)	251	267

For both storms, the duration of high wind speeds was greatest in Spokane and the winds were more intense in Spokane. Average hourly wind conditions, including the number of consecutive hours that the hourly average wind speed remained above the threshold frictional velocity, are as follows:

	November 23, 1990	October 21, 1991
Yakima		
Average wind speed (mph)	26	27
Maximum wind speed (mph)	32	32
Duration (hours)	20	6
Spokane		
Average wind speed (mph)	27	26
Maximum wind speed (mph)	35	38
Duration (hours)	82	15
Pendleton		
Average wind speed (mph)	-	25
Maximum wind speed (mph)	-	35
Duration (hours)	-	7

By modeling PM_{10} concentrations resulting from fugitive dust, CP^3 demonstrated that high wind speed events can produce ambient concentrations in excess of the AAQS over a large portion of eastern Washington (see Sections 3.3 and 4.1.3). PM_{10} concentration plots for three storms, reproduced from data developed by Claiborn et al. (1998), are presented in Annex C. The September 11 (Figure C-2) and November 3, 1993 (Figure C-3) events were major storms that produced significant ambient PM_{10} concentrations. The November 23, 1990 (Figure C-1) storm produced smaller but significant concentrations throughout eastern Washington.

CP^3 modified the land use and soil type data, used to model the November 23 storm, to simulate emissions from the dry Snake River reservoir lake sediments. The Snake River was simulated as a straight line from Kennewick to Clarkston, Washington. When the Snake River reservoirs were modeled as the only emitting sources, the largest predicted 24-hour PM_{10} concentration was less than 5 $\mu g/m^3$ (Figure C-4). The November 23 event was also modeled with the Snake River reservoirs and the remaining eastern Washington land cover. This plot (Figure C-5) may be compared to the contour plot for the November 23 storm modeled without the simulated Snake River.

Major storms that produce significant PM_{10} concentrations over large areas affect communities throughout eastern Washington. The largest population centers, such as the Tri-Cities area, may be subjected to the largest concentrations. A map showing the distribution of the eastern Washington population is presented in Annex D, and may assist in interpreting the contour plots presented in Annex C.

4.3.3.3 Windblown Hazardous Air Pollutant Concentrations

The maximum predicted PM_{10} concentrations resulting from windblown Snake River reservoir sediments are used to estimate the risk associated with contaminants in the sediments. To provide a degree of conservatism, the maximum ambient 24-hour PM_{10} concentration predicted by CP^3 for Snake River sediment emissions was increased by a factor of 10 to 50 $\mu g/m^3$. Assuming that 10 storm events in 1 year produce the same predicted maximum 24-hour concentrations, the resulting annual average concentration would be 1.4 $\mu g/m^3$. This analysis assumed that metal and organic contaminant concentrations throughout the reservoir sediments equal the maximum measured concentrations of these pollutants (Appendix C). The resulting worst-case HAP air concentrations will be less than the risk-based ASILs (Table 4-16).

The water quality and sediment field studies and subsequent data analysis focused on identifying potential impacts associated with erosion, suspension, and transport of sediments resulting from increased river flows during drawdown. From the characterization of sediment samples, summarized in Technical Appendix C (Water Quality), manganese, dioxin and its constituents, and total DDT and its constituents were identified as contaminants of concern. Based on the analysis above, contaminated sediments are not of concern from an air quality perspective.

Table 4-16. Hazardous Air Pollutant Concentrations

Pollutant	ASIL ($\mu g/m^3$)	Averaging Period	Uniform Soil Concentration Needed to Produce ASIL (ppm)	Maximum Measured Soil Concentration (ppm)	Air Concentration as Percent of ASIL (percent)
Metals					
Arsenic	0.00023	Annual	168	7.49	4.46
Barium	1.7	24-hour	34,000	234.8	0.69
Beryllium	0.00042	Annual	307	0.8	0.26
Cadmium	0.00056	Annual	409	0.05	0.01
Chromium	1.7	24-hour	34,000	27.1	0.08
Cobalt	0.17	24-hour	3,400	13.2	0.39
Copper	3.3	24-hour	66,000	28.6	0.04
Lead	0.5	Annual	365,000	14.9	<0.01
Manganese	0.04	24-hour	800	797.9	99.74
Mercury	0.17	24-hour	3,400	0.36	0.01
Molybdenum	17	24-hour	340,000	0.34	<0.01
Nickel	0.0021	Annual	1,533	18.5	1.21
Selenium	0.67	24-hour	13,400	2.04	0.02
Silver	0.33	24-hour	6,600	0.05	<0.01
Thallium	0.33	24-hour	6,600	0.26	<0.01
Vanadium	0.17	24-hour	3,400	58.0	1.71
Zinc	17	24-hour	340,000	71.0	0.02
Organics					
Dioxin	3.00E-08	Annual	0.022	0.000001	<0.01
DDT	0.01	Annual	7,300	0.0328	<0.01

Should a more refined analysis of HAP emissions be warranted, the following additional work would be required before the potential airborne concentrations of these pollutants can be more precisely estimated:

- Characterize the surface concentrations of the sediments that would be subject to wind erosion [not the average of the upper 0.6096 m (2 feet) of sediment, as reported by Appendix C].

- Determine the horizontal extent of the contaminants and the maximum and average contaminant concentrations.

- Estimate 24-hour and annual emissions of hazardous and toxic air pollutants resulting from emissions from these sources.

- Perform dispersion modeling for those pollutants emitted in significant quantities to determine if people living near the reservoirs are at risk.

4.3.4 Power Plant Emissions

The lower Snake River dams include 3,500 MW of installed peak electrical generating capacity. Under the Dam Breaching alternative, all hydropower from the dams would be lost and would have to be replaced by a combination of energy strategies. Two options for replacing the lost hydropower have been evaluated:

- The New Power Plants Scenario, whereby the lost hydropower would be replaced by installing new natural-gas fired power plants. For this scenario, the new power plants would result in a net increase in regional air pollutant emissions.

- The Zero Carbon scenario, whereby the lost hydropower would be replaced by a combination of regional energy conservation and/or development of non-polluting renewable energy resources. For this scenario there would be no net increase in carbon dioxide emissions (hence the term "Zero Carbon") or other air pollutants.

The Technical Report on Hydropower Costs and Benefits (DREW, 1999a) evaluated the costs associated with replacing power lost from the lower Snake River hydropower facilities and concluded that it would not be necessary to replace all 3,500 MW of peak hydropower capacity. The most likely scenario with dam breaching is construction of 1,550 MW of peak-generating capacity somewhere in the Pacific Northwest by 2010 by encouraging installation of combined-cycle combustion turbine power plants. The replacement power plants would not have to operate continuously at their peak rated capacity. This future replacement scenario, referred to as the New Power Plants Scenario, was used to evaluate emission impacts.

4.3.4.1 New Power Plants Scenario

Description of New Thermal Power Plants

Construction of new power plants in Oregon and Washington has proceeded in the past ten years and will continue in the future regardless of the status of the lower Snake River dams. A survey of recent air discharge permit applications for power plants was completed for this study. The characteristics of 16 recently constructed or proposed power plants in Washington and Oregon are presented in Table 4-17.

The predominant type of thermal power plant recently added to the west coast power system has been natural gas-fired combined-cycle combustion turbine plants (DREW, 1999a). Nine of these types of power plants have been constructed in Oregon and Washington since 1991 to meet increases in power demand, and more are being planned regardless of the status of the lower Snake River dams. The Power System Analysis concluded that this type of new plant represents the most cost-effective option over a wide range of economic and environmental factors. Proposed power plants were included as sources in the power plant emission estimates for all three alternatives investigated by this analysis.

Future power generating requirements in the New Power Plants Scenario include power generators to replace hydrogeneration capacity lost if the Dam Breaching alternative is implemented. An estimate of where new power plants may be located is useful to the analysis. The hydropower study team, after reviewing studies conducted by the Northwest Power Planning Council and BPA, concluded that the following locations are the most favorable to meet power demand and transmission reliability needs:

Location	Number of Combined Cycle Plants	Peak Capacity of Individual Plants
Tri-Cities area, Washington	2	250 MW
Hermiston, Oregon	1	250 MW
Puget Sound area, Washington	3	250 MW

Table 4-17. Summary of Recent Power Plants Constructed or to Be Constructed in the Pacific Northwest

Generic Facility Designation	Location	Year Permitted or Constructed	Number of Units	Total MW	Host
Plant 1	Chehalis, WA	_[1/]	2	620	Yes
Plant 2	Goldendale, WA	_[1/]	2	214	No
Plant 3	Boardman, OR	1995	2	504	Yes
Plant 4	Bellingham, WA	1991	3	243	Yes
Plant 5	Hermiston, OR	1993[2/]	2	476	Yes
Plant 6	Hermiston, OR	1998[2/]	2	548	No
Plant 7	Klamath, OR	1996	1	305	Yes
Plant 8	Bingen, WA	1998	1	63	Yes
Plant 9	Longview, WA	1996	1	96	Yes
Plant 10	Anacortes, WA	1993	3	140	Yes
Plant 11	Creston, WA	_[1/]	4	714	No
Plant 12	Vancouver, WA	1997	1	248	No
Plant 13	Satsop, WA	_[1/]	2	454	No
Plant 14	Sumas, WA			120	Yes
Plant 15	Sumas, WA	_[1/]	3	507	No
Plant 16	Ferndale, WA		2	245	Yes

[1/] Not yet constructed.

[2/] Application submitted.

In the deregulated power industry, the new power plants would be privately owned, and the actual sites would be decided by market conditions. There is a high degree of uncertainty regarding specific siting and timing of plant construction. Accordingly, these assumed plant locations and sizes are totally hypothetical.

Assumed Power Plant Emissions and Estimated Impacts to Local Air Quality

Although the exact locations of future replacement power plants are unknown, it is assumed that the replacement power plants would be similar to those that have recently been permitted and/or constructed elsewhere in the Pacific Northwest. It is also assumed that the emissions and the ambient air quality impacts adjacent to the future replacement plants would be similar to those of the recently constructed plants. In order to evaluate the emissions and impacts to local air quality near the power plants, the air quality permits for two recently permitted power plants were reviewed:

- The 248 MW River Road Generating Station near Vancouver, Washington, which was constructed in 1997. This plant represents the lower end of the expected size range for any future replacement plants.
- The 660 MW Sumas 2 project at Sumas, Washington, which is currently being permitted by the Washington Energy Facility Siting Evaluation Council (EFSEC). This plant represents the upper end of the expected size range for any future replacement plants.

The expected emission controls, emission rates, and modeled ambient air quality impacts for a relatively small future replacement plant (represented by the 248 MW River Road Generating Station) are summarized in Table 4-18. The expected emissions and ambient air quality impacts for a relatively large future replacement plant (represented by the 660 MW Sumas 2 Project) are summarized in Table 4-19.

Table 4-18. Summary of Air Quality Impacts from a 248 MW Power Station

Facility	River Road Generating Station, Vancouver, Washington Existing facility, began operation in 1997
Capacity	248 MW; single turbine; natural gas primary fuel; diesel fuel as backup
Air quality permits	Not subject to PSD or EFSEC permitting. NOC from Southwest Clean Air Agency
Emission controls	NO_x: Low-NO_x combustor with selective catalytic reduction (SCR). NO_x limit = 4 ppm while burning natural gas CO: oxidation catalyst. CO limit = 6 ppm while burning natural gas

Air Pollutant Emissions and Ambient Concentrations

		Annual Ambient Concentrations Caused Solely by Power Plant Emissions ($\mu g/m^3$)		24-Hour Ambient Concentrations Caused Solely by Power Plant Emissions ($\mu g/m^3$)	
Pollutant	**Emission Rate (tons per year)**	**Modeled Conc.**	**Allowable Limit**	**Modeled Conc.**	**Allowable Limit**
NO_x	99	0.2	100	–	–
CO	88	–	–	50[1/]	10,000
SO_2	48	0.1	52	19	262
PM_{10}	41	0.07	50	6	150
Formaldehyde	0.45	0.0018	0.077	–	–
Ammonia	93	–	–	0.8	100

Source: Mint Farm Generating LLC, 1999; SWAPCA, 2000.
[1/] 8-hour concentration.

Table 4-19. Summary of Air Quality Impacts from a 660 MW Power Station

Facility	Sumas Energy 2 Generation Facility, Sumas, Washington Proposed facility, currently completing permit process
Capacity	2 turbines; 660 MW total; supplemental duct burners for peaking; diesel fuel as backup
Air Quality Permits	PSD permit from Washington EFSEC
Emission Controls	NO_x: Low-NO_x turbines with SCR. NO_x limit = 2 ppm while burning natural gas CO: oxidation catalyst. CO limit = 2 ppm while burning natural gas

Air Pollutant Emissions and Ambient Concentrations

Pollutant	Emission Rate (Tons Per Year)	Annual Ambient Concentrations Caused Solely by Power Plant Emissions ($\mu g/m^3$)		24-Hour Ambient Concentrations Caused Solely by Power Plant Emissions ($\mu g/m^3$)	
		Modeled Conc.	Allowable Limit	Modeled Conc.	Allowable Limit
NO_x	236	0.5	100	–	–
CO	101	–	–	20[1/]	10,000
SO_2	45	0.1	52	14	262
PM_{10}	223	0.5	50	10	150
Formaldehyde	0.1	0.0008	0.077	–	–
Ammonia	139	–	–	4	100
Sulfuric Acid Mist	8	–	–	3.0	3.3
CO_2	2.4 million	–	–	–	–

Acid Deposition and Visibility Impacts at North Cascades National Park

Environmental Impact	Impact Caused by Power Plant Emissions	Recommended Limit
Nitrogen deposition at North Cascades National Park (kg/hectare/yr)	0.0014	0.005 – 0.10
Visibility impact at North Cascades National Park while firing primary natural gas (increase in 24-hour b-ext)	2.5%	5%
Visibility impact at North Cascades National Park while firing backup oil fuel (increase in 24-hour b-ext)	7.5%	5%

Source: Sumas Energy 2 Generating Facility, 2000; EFSEC, 2000.
[1/] 8-hour concentration.

Comparison of the air quality impacts for those two actual plants shows the following:

- Permitting Requirements – The River Road Generating Station required only a conventional NOC air quality permit from the local air quality agency because its rated capacity is less than 250 MW (the threshold for permitting by EFSEC) and it emits less than 100 tons per year of any single pollutant (the threshold for PSD permitting). The relatively large Sumas 2 Project requires a PSD permit issued by EFSEC.

- Emission Controls – Both plants use the same emission controls. NO_x is controlled by Selective Catalytic Reduction (SCR) with ammonia injection. CO, VOC, and HAPs are controlled by an oxidation catalyst. SO_2 (emitted mainly from backup oil combustion) is controlled by use of low-sulfur oil and restrictions on the annual usage of fuel oil.

- Ambient Air Quality Impacts – The worst-case local ambient concentrations of criteria pollutants and toxic air pollutants adjacent to both plants are well below Washington's allowable limits. The air quality impacts at the Sumas 2 project were less than the allowable PSD Class II increments. The local air quality impacts were estimated using EPA's

Industrial Source Complex (ISC) model and local meteorological data. The modeled concentrations listed in Tables 4-18 and 4-19 include only the impacts contributed by the power plants themselves without adding local background concentrations. If the project proponents elected to build in a location with exceptionally high background concentrations, then additional emission controls might be required to ensure that the total ambient concentration (power plant impact plus background) is less than the allowable limits.

- Impacts to Class I Areas – The Sumas 2 Project is subject to PSD permitting, so the project was required to model impacts of acid deposition and visibility at regional Class I areas. The concentrations of all pollutants at the regional Class I areas were modeled to be less than the allowable PSD Class I increments. Annual-average acid deposition was modeled using EPA's CALPUFF model, and was well below threshold levels specified by the U.S. Forest Service for vegetation degradation. Worst-case visibility impacts would occur during the few days per year when the facility is permitted to use backup fuel oil. The visibility impacts at the nearest Class I areas were modeled to exceed acceptable thresholds if maximum backup fuel oil usage occurred on days with worst-case meteorological conditions and during the most restrictive background conditions.

Increase in Regional Air Pollutant Emissions

The air quality impacts described in the previous section relate mainly to the local area within a few miles of the individual replacement power plants. The overall emission increases caused by the combined replacement plants across the western United States could affect regional and global air quality. Increases in western regional CO_2 emissions could affect global climate change. Increases in regional emissions of NO_x, SO_2, and PM_{10} could affect regional acid deposition and regional visibility.

The PROSYM power system model (described in Section 3.4 of this appendix) was used to estimate regional emissions for all WSCC electrical generating units throughout the western United States. The PROSYM model estimates for the New Power Plants Scenario represent year 2010 emissions from the following combination of generating units:

- All existing generating units (approximately 2,000 units) in the WCSS
- Additional natural gas-fired combined cycle units that will be constructed between 2000 and 2010 regardless of the fate of the Snake River hydrofacilities to meet growth in the demand for electricity
- 1,550 MW of peak replacement power.

The net change in western regional power-generating emissions following drawdown is the difference in the values for the New Power Plants Scenario minus the year 2010 Existing Conditions. Table 4-20 summarizes the net changes in western regional emissions. The WSCC regional emissions for

Table 4-20. Percent Increase in Year 2010 Electrical Generating Emissions Throughout WSCC Region

Scenario	Emissions (thousands of tons per year) CO_2	NO_x	PM_{10}	SO_2
Year 2010 Existing Conditions	414,234	57.8	49.3	457.4
Year 2010 New Power Plants	418,870	58.1	49.5	459.6
Net increase in year 2010 WSCC regional	4,600	0.3	0.2	2.2
Percent increase in WSCC regional emissions	1.1%	0.5%	0.4%	0.4%

the Year 2010 Existing Conditions were discussed in Section 4.1.4 of this appendix. The Year 2010 WSCC emissions for the New Power Plants Scenario are itemized in Table 4-21.

Table 4-20 indicates that WSCC regional CO_2 emissions would increase by 4.2 million metric tons per year (4,600,000 tons/year) compared to the Year 2010 Existing Conditions. NO_x emissions would increase by 272 metric tons per year (300 tons/year). PM_{10} emissions would increase by 181 metric tons per year (200 tons/year).

Impacts to Greenhouse Gas Emissions and Global Warming

Replacement power plants constructed in the western United States would increase regional emissions of CO_2 and could affect global warming. Because CO_2 emissions from each power plant cause global impacts rather than local impacts, the CO_2 emissions from the combined power plants are best compared to regional and nationwide CO_2 emissions.

In the 8-year period from 1990 to 1998, nationwide United States CO_2 emissions increased from 9,806 million metric tons to 10,932 million metric tons (10,809 to 12,050 million tons), an increase of about 11 percent. If GHG emission rates continue to increase at the same rate, national CO_2 emissions in 2010 will be about 12,519 million metric tons (13,800 million tons). For the planning period of 1990-2010, this represents a nationwide CO_2 emission increase of 2,713 million metric tons (2,991 million tons). For comparison, the 1,500 MW capacity of replacement power plants would increase CO_2 emissions in the WSCC region by 4.2 million metric tons per year (4.6 million tons/year). Based on these forecasted emission estimates, the relative impact of the New Power Plants Scenario can be summarized as follows:

- In the year 2010, the total WSCC electrical generating CO_2 emissions are forecasted to be about 3.0 percent of the nationwide total emissions.
- The net CO_2 emission increase caused by the 1,550 MW capacity of new replacement power plants would be about 1.1 percent of the WSCC western regional emissions.
- The net CO_2 emission increase caused by the 1,550 MW capacity of new replacement power plants would be about 0.14 percent of the nationwide CO_2 increase during the period 1990 to 2010.

4.3.4.2 Zero Carbon Scenario

As described in Section 4.3.4.1, replacement power plants for the New Power Plants scenario would increase CO_2 emissions from western regional electric utilities by 4.2 million tons per year compared to the Existing Conditions alternative. This predicted CO_2 emission increase is roughly 1 percent of the total for all combined electrical generating units within the WSCC region.

An emission increase of that magnitude is counter to the United States Climate Change Action Plan, which includes a goal to reduce nationwide CO_2 emissions to year 1990 levels. Therefore, the U.S. Army Corps of Engineers, Northwest Power Planning Council (NWPPC), and Natural Resources Defense Council (NRDC) have evaluated the feasibility of an alternative to offset the lost hydropower from the lower Snake River dams without installing any new natural-gas fired power plants. Under this alternative the CO_2 emissions for the Dam Breaching alternative would be the same as for the Existing Conditions alternative. This alternative is therefore designated the Zero Carbon Scenario.

Table 4-21. Year 2010 WSCC Regional Emissions for New Power Plants Scenario

Generation Resource	Year 2010 Emissions Throughout WSCC (thousands of tons per year)							
	CO	CO_2 [1/]	NO_x [1/]	PM_{10}	SO_2 [1/]	VOC	Benzene	Formaldehyde
Coal								
Arizona/New Mexico	76	77,957	16	19	173	0.2	0.001	0.0002
Canada	45	46,060	8	8	75	0.1	0.0007	0.0001
Northwest	12	12,522	2	4	41	0.04	0.0002	0.00004
Rocky Mountains	117	120,144	24	18	165	0.3	0.002	0.0003
Fuel Oil								
FO #2	0.3	1,098	0.04	0.004	0.4	0.001	-	0.00008
FO #6	0.01	36	0.003	0.0003	0.1	0.00007	-	0.000006
Natural Gas								
Alberta	0.2	190	0.002	0.0002	0.02	0.0001	-	0.00001
Arizona/New Mexico	5	4,844	0.7	0.07	0.03	0.04	-	0.004
British Columbia	0.3	304	0.004	0.0003	0.003	0.0002	-	0.00002
Future combined cycle	91	92,713	2	0.2	0.6	0.1	-	0.01
Northern California	10	10,583	0.8	0.08	0.07	0.04	-	0.005
PG&E IPPs	13	12,792	1	0.1	1	0.06	-	0.006
Pacific Northwest	9	8,926	0.2	0.02	0.06	0.009	-	0.001
Rocky Mountains	3	3,154	0.4	0.04	0.02	0.02	-	0.003
Rocky Mountains/Colorado	2	1,905	0.1	0.01	0.01	0.006	-	0.0006
Southern California	12	12,710	0.6	0.06	0.09	0.03	-	0.004
SCE IPPs	12	11,728	1	0.1	3	0.06	-	0.007
SDG&E IPPs	0.7	752	0.07	0.006	0.005	0.004	-	0.0004
Total System Emissions	**408**	**418,870**	**58.1**	**49.5**	**459.6**	**1**	**0.004**	**0.04**

1/ Source: DREW, 1999a.

The engineering and economic details of the Zero Carbon scenario are described in Section 5.9.4 of the EIS. The PROSYM power model was used to determine the amount of non-polluting energy conservation that would be required to offset the emissions from new thermal power plants. Under the Zero Carbon Scenario, the 1,550 MW of lost hydropower would be offset by a combination of energy conservation measures and clean, renewable generation measures. The actual net loss of hydropower production from dam breaching would be 940 aMW, according to a report by the Natural Resources Defense Council (2000). This evaluation considers impacts from an operational base case from increased spill, increased fish barge transport, and reoptimizing the electricity generating system once the dams are removed. The Natural Resources Defense Council study assumes that 1,091 aMW of power (75 percent from conservation and the remaining amount from non-hydro renewable energy sources such as wind and solar) would be required to replace the lost 940 aMW of hydropower without any increase in carbon emissions from the base case due to timing considerations for reduced comsumption. A concurrent analysis was conducted by the Corps with slightly different assumptions and very similar conclusions. In the Corps analysis, approximately 820 aMW of thermal power would have to be replaced by conservation for substantially no net increase in carbon emissions in 2010 compared to the base case of leaving the dams in place. Because the load curves of lower Snake River hydropower differ from the load curves for available conservation, a total of 1,150 aMW of conservation would have to be enacted to offset the 820 aMW of lost hydropower. The 1,150 aMW of new energy conservation would represent a decrease of 5.3 percent of the forecasted load in the WSCC region for the year 2010.

It is uncertain whether 1,150 aMW of new energy conservation is readily available within the region. In addition, there is uncertainty regarding the relative costs of 1,150 aMW of new conservation compared to the cost of 820 aMW of new thermal power plants. Based on published reports (NWPPC, 1996; NRDC, 2000), as of 1996 there were an estimated 1,535 aMW of low-cost energy conservation available to BPA ("low-cost" conservation is defined as costing less than 3 cents per kw-hr). A summary of the identified conservation measures is given in Table 4-22. However, voluntary measures have already consumed about 500 aMW of available low-cost conservation since 1996. Therefore, it is possible that the Zero Carbon Scenario would require enactment of additional resources beyond low-cost conservation. Such additional measures could include pursuing high-cost energy conservation and subsidizing development of non-polluting renewable energy systems such as wind power.

Table 4-22. Achievable Conservation for Zero Carbon Scenario

End Use Sector	Achievable Conservation (aMW)
Freezers	15
Refrigerators	45
Water heating	335
Residential lighting	30
New residential space heating	140
Existing residential space heating	25
New commercial	230
Existing commercial	95
Commercial renovation/remodel	50
New non-aluminum industrial	225
Existing non-aluminum industrial	335
Direct service aluminum industrial	Not estimated
Irrigated agriculture	10
Total	**1,535**

5. Comparison of Alternatives

This section compares the atmospheric emissions estimated for the Existing Conditions, Major System Improvements, and Dam Breaching alternatives, and includes a brief discussion of potential mitigation measures, cumulative effects, and unavoidable adverse effects.

This analysis estimated criteria air pollutants and TAP emissions for the Existing Conditions, Major System Improvements, and Dam Breaching alternatives. The air quality issues related to the Lower Snake River Juvenile Salmon Migration Feasibility Study are:

- Fugitive dust emissions resulting from deconstruction of the dams
- A change in the quantity and distribution of vehicle emissions as commodities are shifted from barge to truck and rail
- Fugitive dust emissions resulting from dry exposed lake sediments during high wind speed events
- Atmospheric emissions associated with replacement power generation by thermal power plants.

Estimated air quality impacts are presented below by alternative. Cumulative effects, mitigation measures, unavoidable adverse effects, and incomplete information are also discussed below.

5.1 Summary of Emissions by Alternative

Emissions estimated in Section 4 are summarized in Table 5-1. Emission increases above those estimated for the Existing Conditions alternative are presented in Table 5-1 for the Major System Improvements and Dam Breaching alternatives. Transportation-related emissions are an average of the estimates produced from the EWITS and Transportation Analysis data. The Transportation Analysis estimated the change in emissions following drawdown. The Dam Breaching transportation-related emissions are indeterminant. Worst-case ambient concentrations, as a percent of the AAQS, are presented for representative Existing Conditions and Dam Breaching emissions sources in Table 5-2. The data in Table 5-2 represent the maximum ambient air quality concentrations predicted for any receptor as part of the evaluation of that pathway. As indicated by Table 5-2, emissions associated with the EIS alternatives result in ambient concentrations less than the AAQS. PM_{10} concentrations associated with deconstruction activities will be less than the AAQS once public access restrictions are defined.

5.2 Existing Conditions Alternative

5.2.1 Direct and Indirect Effects

No emission increases are estimated for the Existing Conditions, which represents current conditions projected to 2010. Therefore, this alternative would have no direct or indirect air quality effects. Under this alternative, Snake River barge traffic would continue and new power plants would continue to be built as power demand increases. Emissions from these new plants have been factored into the analysis.

Table 5-1. Summary of Emissions in Tons

	Emissions (tons per year)							
	CO	CO_2	NO_x	PM_{10}	SO_2	VOC	Benzene	Formaldehyde
Existing Conditions								
Demolition								
Transportation	235	20,680	1,705	52	266	285	1	1
Windblown Dust								
Power Generation	403,624	414,233,886	57,757	49,267	457,383	1,132	4	45
Total	**403,859**	**414,254,566**	**59,462**	**49,319**	**457,649**	**1,417**	**5**	**46**
Major System Improvements								
Construction								
Transportation	235	20,680	1,705	52	266	285	1	1
Windblown Dust								
Power Generation	403,624	414,233,886	57,757	49,267	457,383	1,132	4	45
Total	**403,859**	**414,254,566**	**59,462**	**49,320**	**457,649**	**1,417**	**5**	**46**
Change from Existing System	0	0	0	1	0	0	0	0
New Power Plants Scenario								
Demolition				1,193				
Transportation	227	19,976	1,759	63	198	383	1	1
Windblown Dust				6,292				
Power Generation	407,758	418,870,000	58,100	49,463	459,600	1,134	4	45
Total	**407,985**	**418,889,976**	**59,859**	**57,011**	**459,798**	**1,517**	**5**	**46**
Change from Existing System	4,126	4,635,410	397	7,692	2,149	101	0	0
Zero Carbon Scenario								
Demolition				1,193				
Transportation	227	19,976	1,759	63	198	383	1	1
Windblown Dust				6,292				
Power Generation	403,624	414,233,886	57,757	49,267	457,383	1,132	4	45
Total	**403,851**	**414,253,862**	**59,516**	**56,815**	**457,581**	**1,515**	**5**	**46**
Change from Existing System	(8)	(704)	54	7,496	(68)	98	0	0

Table 5-2. Summary of Maximum Predicted Ambient Air Concentrations

		Concentration as a Percent of the Ambient Air Quality Standard[1/]				
Pollutant	Period	Demolition	Transportation		Windblown Dust	Power Generation
Existing Conditions			Shoreline[3/]	Highway[4/]		
CO	1-hour		3	1		
	8-hour		7	2		
NO_2	Annual		45	25		
PM_{10}	24-hour		25	3		
	Annual		2	3		
SO_2	1-hour		93	3		
	3-hour		42	1		
	24-hour		94	2		
	Annual		11	3		
New Power Plants Scenario						
CO	1-hour		-	1		0.1
	8-hour		-	4		0.1
NO_2	Annual		-	33		0.5
PM_{10}	24-hour	< 100[2/]	-	5	3	7
	Annual	30	-	4	3	1
SO_2	1-hour		-	3		7
	3-hour		-	2		4
	24-hour		-	3		7
	Annual		-	4		0.2

[1/] Data are the maximum ambient air quality concentrations predicted for any receptor for the given alternative.
[2/] The concentration is dependent on the public exclusion area.
[3/] Adjacent to the Snake River upriver of the Ice Harbor Dam.
[4/] Adjacent to the intersection of US 395 and SR 260.

5.2.2 Cumulative Effects

No new air pollution sources are required for the Existing Conditions alternative, so this alternative would not exacerbate any existing air quality concerns in the region. No new construction activities or power plants would be required as a result of the Existing Conditions alternative. No changes in transportation-related emissions would occur.

Storms will continue to generate fugitive emissions that will occasionally result in temporary PM_{10} concentrations that exceed the air quality standard. Eastern Washington industries will continue to be sources of criteria air pollutants, GHGs, and HAPs. An example of these emissions is presented in Table 2-3. Eastern Washington traffic will continue to be a source of air pollutants. Emissions estimates representative of Snake River commodity transportation for the Existing Conditions alternative are tabled on page P4-4. Emissions from western states power production are estimated in Table 4-8. Ambient air quality concentrations resulting from emissions associated with the Existing Conditions alternative are presented in Section 4.1. Based on a review of the estimated emissions, predicted ambient concentrations resulting from these emissions, and discussions with Ecology, the impacts associated with the Existing Conditions alternative are less than the AAQS. Indirect impacts, such as emissions from aluminum plants outside of the Snake River region, are subject to sociological and economic conditions beyond the scope of the assessment. Lower Snake

River regional emissions associated with the four air quality issues investigated in this assessment are tabled with a comparison of other alternative-specific emissions in Table 5.1.

5.2.3 Mitigation Measures

No mitigation measures are required for the Existing Conditions alternative. No new construction activities or power plants would be required as a result of the Existing Conditions alternative. No changes in transportation-related emissions would occur.

5.2.4 Unavoidable Adverse Effects

The Existing Conditions alternative would not cause any adverse air quality impacts.

5.2.5 Incomplete Information

No additional information related to air quality is required for the Existing Conditions alternative.

5.3 Major System Improvements Alternative

5.3.1 Direct and Indirect Effects

Minor construction-related emission increases are anticipated for the Major System Improvements alternative. Therefore, only minor direct or indirect air quality effects would result. As with the Existing Conditions alternative, Snake River barge traffic would continue, and no new power plants would be required as a result of actions taken at the Snake River dams. Emission estimates for the Major System Improvements alternative are identical to those of the Existing Conditions alternative.

5.3.2 Cumulative Effects

Cumulative effects for the Major System Improvements alternative are the same as for the Existing Conditions alternative.

Storms will continue to generate fugitive emissions that will occasionally result in temporary PM_{10} concentrations that exceed the air quality standard. Eastern Washington industries will continue to be sources of criteria air pollutants, GHGs, and HAPs. An example of these emissions is presented in Table 2-3. Eastern Washington traffic will continue to be a source of air pollutants. Emissions estimates representative of Snake River commodity transportation for the Major Systems Improvements alternative are tabled on page P4-4. Emissions from western states power production are estimated in Table 4-8. Ambient air quality concentrations resulting from emissions associated with the Major Systems Improvements alternative are presented in Section 4.1. Based on a review of the estimated emissions, predicted ambient concentrations resulting from these emissions, and discussions with Ecology, the impacts associated with the Major Systems Improvements alternative are less than the AAQS. Indirect impacts, such as emissions from aluminum plants outside of the Snake River region, are subject to sociological and economic conditions beyond the scope of the assessment, although traditional low-cost hydropower is critical to their continued operations. Lower Snake River regional emissions associated with the four air quality issues investigated in this assessment are tabled with a comparison of other alternative-specific emissions in Table 5-1.

5.3.3 Mitigation Measures

No mitigation measures related to air quality are required for the Major System Improvements alternative.

5.3.4 Unavoidable Adverse Effects

The Major System Improvements alternative would not cause any adverse air quality impacts.

5.3.5 Incomplete Information

No additional information related to air quality is required for the Major System Improvements alternative.

5.4 Dam Breaching Alternative

5.4.1 Direct and Indirect Effects

As listed in Table 5-1, the Dam Breaching alternative would result in increased air pollutant emissions compared to the Existing Conditions alternative. This pathway would result in fugitive emissions (PM_{10}) from demolition, transportation emissions associated with the loss of barge transportation (criteria air pollutants), fugitive dust from exposed reservoir sediments, and emissions associated with replacement power generation (criteria air pollutants, HAPs, and GHGs). The transportation-related emission estimates do not consider tire and brake emissions.

However, as listed in Table 5-2, the increased emissions from project-related activities would not cause any ambient air pollutant concentrations greater than the AAQS. In addition, the project-related emissions would not adversely affect any nearby nonattainment areas.

Increased CO_2 emissions caused by the replacement power plants would account for about one percent of the western regional emissions from WSCC's power generating units.

5.4.2 Cumulative Effects

Storms will continue to generate fugitive emissions that will occasionally result in temporary PM_{10} concentrations that exceed the air quality standard. Eastern Washington industries will continue to be sources of criteria air pollutants, GHGs, and HAPs. An example of these emissions is presented in Table 2-3. Demolition-related emission estimates are tabulated on page P4-11. Eastern Washington traffic will continue to be a source of air pollutants. The change in emissions representative of Snake River commodity transportation for the Dam Breaching alternative are tabled on page P4-17. Emissions from western states power production are estimated in Table 4-21. Ambient air quality concentrations resulting from emissions associated with the Dam Breaching alternative are presented in Section 4.3. Based on a review of the estimated emissions, predicted ambient concentrations resulting from these emissions, and discussions with Ecology, the impacts associated with the Dam Breaching alternative are less than the AAQS. Indirect impacts, such as emissions from aluminum plants outside of the Snake River region, are subject to sociological and economic conditions beyond the scope of the assessment. Lower Snake River regional emissions associated with the four air quality issues investigated in this assessment are tabled with a comparison of other alternative-specific emissions in Table 5-1.

5.4.2.1 Deconstruction Fugitive Dust

According to Appendix D, drawdown may take place during the eastern Washington storm season (September through November). Should a high wind speed event occur during deconstruction, lake sediments and excavated material would be available for erosion. The fugitive dust problem would be exacerbated if all four dams were removed at once.

5.4.2.2 Transportation-Related Emissions

Increased tailpipe emissions from haul trucks that would replace the existing barge system would probably not cause any significant cumulative impacts. Existing background concentrations of NO_x and CO (the primary tailpipe emissions) along the expected haul truck routes are much lower than the AAQS. The increased emissions would not significantly increase the background concentrations.

5.4.2.3 Windblown Fugitive Dust

The Columbia Plateau region already experiences high PM_{10} concentrations, and Ecology indicates that in the future, portions of the region could be designated as nonattainment areas. Construction-related fugitive emissions could be effectively controlled, so temporary impacts during dam deconstruction would probably not exacerbate regional problems. However, long-term windblown dust from the dry lake beds could be difficult to control. These emissions could exacerbate regional PM_{10} problems that already occur during occasional high wind events.

5.4.2.4 Power Plant Emissions

NO_x and CO emissions from replacement power plants would not exacerbate any existing ambient air quality concerns, even if some of the plants were constructed in urban areas. State air quality regulations would require the power plant emissions to be stringently controlled. Local air quality agency staff have indicated that the increased emissions from any of the replacement plants would not significantly affect their future ability to satisfy the AAQS. CO_2 emissions from replacement power plants could exacerbate future difficulties in reducing national and regional emissions down to historical 1990 levels, as recommended by the United States Climate Change Action Plan.

5.4.3 Mitigation Measures

5.4.3.1 Deconstruction Fugitive Dust

Deconstruction of the dams would incorporate standard construction practices to suppress fugitive dust, such as spraying haul roads with water. Some of the dam core material would be saturated with water, reducing the potential for fugitive dust emissions. Deconstruction of the individual Snake River dams would most likely not take place in the same year.

5.4.3.2 Transportation-Related Emissions

No special mitigation is warranted for highway trucks that would replace the existing barge system. Vehicles will continue to experience efficiency improvements and associated reductions in emissions.

5.4.3.3 Windblown Fugitive Dust

Stringent control of windblown dust from the dry lake beds would be required. Appendix D, Natural River Drawdown Engineering, calls for phased revegetation as the water recedes. In addition, access to the dry lakebed would be restricted, further reducing the availability of erodible material. The analysis assumes that dry sediments are disturbed between high wind-speed events, thereby providing additional erodible material. The emission estimates for windblown dust described in this appendix are believed to be conservatively high.

5.4.3.4 Power Plant Emissions

New power plants would have to install stringent emission controls mandated by Best Available Control Technology. If such emission controls are required, then the replacement plants would not cause significant impacts to ambient air quality. Carbon dioxide emissions from replacement power plants could be minimized by a combination of mitigations. Any replacement plants could be required to achieve a CO_2 emission limit equivalent to Oregon's standards and pay emission fees to fund regional CO_2 reduction efforts. The Zero Carbon Scenario could be used, whereby hydropower lost from the Snake River dams would be replaced by a combination of energy conservation and non-polluting renewable energy.

5.4.4 Unavoidable Adverse Effects

If the lower Snake River dams are breached, deconstruction, transportation, windblown dust, and power plant emissions would take place.

5.4.4.1 Deconstruction Fugitive Dust

Fugitive dust emissions during dam deconstruction can be controlled so the ambient impacts are less than the allowable AAQS. Breaching of the dams would resemble a large construction project. Deconstruction of the dams would probably take several years and/or would be staged, resulting in lower emissions per year.

5.4.4.2 Transportation-Related Emissions

Tailpipe emissions from haul trucks that would replace existing barges would not significantly affect ambient air quality. Emissions of CO, NO_x and SO_2 would decline by 1 to 30 percent. Emissions of PM_{10} and VOCs would increase by 20 to 30 percent above the Existing Conditions alternative emissions. Truck traffic on US 395 would increase by as many as 200 trucks per day (in both directions) during the period of grain hauling. The number of trucks on US 195 at SR 272 would decrease by more than 1,000 trucks per day.

5.4.4.3 Windblown Fugitive Dust

Storms would generate fugitive emissions from the dry lake beds until the vegetation cover becomes established. These new emissions could exacerbate existing problems with regional windblown dust. Emissions from the dry reservoirs would be between 0.4 and 13 percent of the total emissions from eastern Washington agricultural areas during individual windstorms. The resulting ambient concentrations may be a problem, especially if the surface sediments are contaminated.

5.4.4.4 Power Plant Emissions

Emissions from each individual power plant would cause localized increases in ambient concentrations, but the local increases would probably be insignificant compared to the AAQS. Western regional emissions of criteria air pollutants, HAPs, and GHGs would increase by 1 percent or less above the Existing Conditions alternative emissions. CO_2 emissions from replacement power plants would be 0.14 percent of the nationwide increase in emissions during the planning period 1990-2010.

5.4.5 Areas of Possible Future Study

The emission calculations used available data and reasonable values for preliminary information. Because of information gaps, the emissions are considered estimates and are intended for comparison of the alternatives. Furthermore, the estimates are used to predict ambient concentrations resulting from deconstruction, transportation, fugitive dust, and power-related emissions. Additional data and studies are necessary to characterize, in detail, the impacts associated with drawdown. Site specific data are listed below.

5.4.5.1 Deconstruction Fugitive Dust

Construction schedules, moisture and silt content of excavated material and haul roads, areas and volumes of stockpiles, and length of haul roads are required for deconstruction emission estimates. Predicting ambient concentrations resulting from fugitive emissions requires the distances to critical receptors and may require on-site meteorological data and background PM_{10} concentrations. These refined emissions estimates would be prepared as part of the environmental evaluations for each individual dam.

5.4.5.2 Transportation-Related Emissions

The analysis conducted for this appendix indicated that transportation-related emissions will not produce an air quality problem. However, increasing traffic congestion may require modification to critical intersections (addition of extra lanes and signalization), regardless of the status of the Snake River dams. To optimize traffic flow and minimize vehicle emissions, traffic and intersection modeling, similar to analysis presented in this appendix, may be required.

5.4.5.3 Windblown Fugitive Dust

Additional maps of the reservoir topography, surface sediment grain-size analysis, the distribution of fine material within the reservoirs, onsite wind conditions, background concentrations, and the location of sensitive receptors are required to characterize windblown dust. The location, concentration, and extent of contaminated surface sediment are required to characterize hazardous air pollutant emissions. If the regions that include the reservoirs are declared nonattainment areas, post drawdown ambient PM_{10} monitoring adjacent to the dry reservoirs may be required. A modeling analysis, similar to the impact analysis, may be necessary to properly site the monitoring station.

5.4.5.4 Power Plant Emissions

Emissions of criteria and hazardous air pollutants from power plants and ambient concentrations resulting from power plant emissions, including cumulative impacts and air quality-related values in protected areas, will be addressed in permit application documents after specific designs for the plants have been developed.

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7. Glossary

Air pollutants: Pollutants that are anthropogenically added to the atmosphere and cause a deviation from the natural composition of the air. Generally referred to as criteria air pollutants.

Air quality: The condition of the atmosphere that would ensure that public health and public welfare would be protected.

Ambient air quality standards (AAQS): Standards required by the Federal Clean Air Act and enforced by the U.S. Environmental Protection Agency and state and local air quality regulatory agencies that protect public health, provide for the most sensitive individuals, and allow a margin of safety by setting an acceptable level for measured pollutant concentrations. AAQS cannot take into account the cost of achieving the standards.

Area sources: Large areas where air pollutants are emitted directly to the atmosphere, such as roads and agricultural fields.

Best Available Control Technology (BACT): An emission limitation based on the maximum degree of reduction for each air pollutants, considering energy, environmental, and economic impacts.

Bushel-mile: This energy- or emissions-related value expresses the transportation of a bushel of grain a distance of one mile.

Climate: A long-term aggregate of atmospheric conditions involving heat, moisture, and air movement.

Combined-cycle combustion turbines: Electricity producing plant that employs a combustion turbine, a heat recovery steam generator, and a steam turbine.

Concentration: Mass concentration is the amount of a pollutant found in a given volume of air. Concentration by volume refers to the number of pollutant molecules per million or billion air molecules.

Criteria air pollutants: Air pollutants for which ambient air quality standards have been established, including carbon monoxide, lead, particulate matter, nitrogen dioxide, ozone, and sulfur dioxide.

Dam Breaching: In the context of this FR/EIS, dam breaching means removing the earthen portions of the four dams and returning the lower Snake River to a near-natural flow.

Drawdown: The distance that the water surface of a reservoir is lowered from a given elevation as water is released from the reservoir. Also refers to the act of lowering reservoir levels.

Drawdown Regional Economic Workgroup (DREW): A group of regional economists studying the economic issues associated with alternative actions on the lower Snake River.

Emission: The direct release of a pollutant into the air. This analysis does not consider natural emissions such as volcanic eruptions and pollen.

Emission factor: A parameter that relates atmospheric emissions to other quantities such as fuel consumption, industrial production rates, road miles, or wind speed.

Fastest mile (u_{fm}): A wind speed corresponding to a mile of wind movement past a measurement location in the least amount of time.

Fugitive dust: Particulate matter made airborne by wind, human activity, or both, and not released to the atmosphere through a control device such as a stack or vent.

Greenhouse gas (GHG): Air pollutants and air constituents that enhance atmospheric heat retention. Greenhouse gases include carbon dioxide, methane, nitrous oxide, chlorofluorocarbons, partially halogenated fluorocarbons, ozone, and water.

Hazardous air pollutants (HAP): Toxic or carcinogenic emissions. Hazardous air pollutants are listed in Section 112 of the Clean Air Act.

Hydropower: Electricity generated by turbines spun by the power of falling water.

Megawatt (MW): One million watts, a measure of electrical power or generating capacity. A megawatt will typically serve about 1,000 people. The Dalles Dam produces an average of about 1,000 megawatts.

Meteorology: The day-to-day or hour-to-hour condition of the atmosphere. Uses physical processes to interpret and explain atmospheric processes.

Mitigation: To moderate or compensate for an impact or effect.

Nonattainment areas: Geographic areas with measured pollutant concentrations greater than the AAQS.

Peak gust: The maximum wind speed during extremely brief time intervals (one or two seconds).

Plume rise: Elevation of a plume gained from vertical velocity and/or buoyancy. Plume rise plus stack height is the effective plume height.

Point sources: Localized emission sources such as smoke stacks and other industrial sources.

Precipitation: Water in liquid or solid form (rain, drizzle, snow, hail) falling to the earth.

Relative humidity: The ratio of the amount of water vapor in the air to the amount the air could hold at a given temperature and pressure.

Stability: Condition of the atmosphere that influences vertical motion of air. Unstable conditions encourage vertical motion in both directions. Stable conditions discourage vertical motions. Neutral conditions neither encourage nor discourage vertical motion.

Surface bypass collector (SBC) system: System designed to divert fish at the surface before they have to dive and encounter the existing turbine intake screens. SBCs direct the juvenile fish into the forebay, where they are passed downstream either through the dam spillway or via the juvenile fish transportation system of barges and trucks.

Surface roughness: A distance that is proportional to the dimension of objects penetrating the surface. A low surface roughness characterizes smooth surfaces.

Threshold frictional velocity (u_{tv}): The minimum wind speed required to begin to move erodable surface particles.

Ton-mile: An energy- or emissions-related value that expresses the transportation of one ton of a commodity a distance of one mile.

Vehicle emissions: Generally, tailpipe emissions resulting from combustion. Can also refer to tire, brake pad, and roadway wear.

Volatile organic compounds (VOC): Any organic compound, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, which participates in atmospheric photochemical reactions.

Wind erosion: Removal of surface particles by the action of wind.

Windrose: Depicts the joint frequency of occurrence, in percent, of wind speed and wind direction categories, for a particular location and time period. The radials of the windrose indicate the direction from which the wind is blowing. The length of the radials indicates the frequency of occurrence for that direction. The width of the radials indicates the wind speed class.

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ANNEX A

SUPPLEMENTAL CLIMATOLOGY DATA

Source: National Climatic Data Center (NCDC)

NORMALS, MEANS, AND EXTREMES

PENDLETON, OR (PDT)

LATITUDE: 45° 41' 54" N | LONGITUDE: 118° 50' 03" W | ELEVATION (FT): GRND: 1482 BARO: 1507 | TIME ZONE: PACIFIC (UTC+ 8) | WBAN: 24155

	ELEMENT	POR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F	NORMAL DAILY MAXIMUM	30	39.7	46.9	54.2	61.3	70.0	79.5	87.8	86.2	76.3	63.7	48.9	40.5	62.9
	MEAN DAILY MAXIMUM	50	39.3	46.2	53.6	61.5	70.2	78.6	87.6	85.7	76.7	63.5	48.8	40.9	62.7
	HIGHEST DAILY MAXIMUM	62	70	75	79	91	100	108	110	113	102	92	77	67	113
	YEAR OF OCCURRENCE		1995	1996	1964	1977	1986	1961	1939	1961	1955	1980	1975	1980	AUG 1961
	MEAN OF EXTREME MAXS.	50	58.5	62.3	68.2	77.5	88.0	94.6	101.2	99.5	92.4	80.1	65.7	59.5	79.0
	NORMAL DAILY MINIMUM	30	27.2	31.6	35.4	39.4	45.8	52.9	58.0	57.7	49.9	41.0	34.1	27.9	41.7
	MEAN DAILY MINIMUM	50	26.3	30.8	34.8	39.6	46.1	52.5	57.9	57.4	50.2	41.1	33.6	28.4	41.6
	LOWEST DAILY MINIMUM	62	-22	-18	1	18	25	35	42	40	30	11	-12	-19	-22
	YEAR OF OCCURRENCE		1957	1950	1993	1936	1954	1991	1971	1980	1970	1935	1985	1983	JAN 1957
	MEAN OF EXTREME MINS.	50	6.3	14.3	23.6	30.2	35.3	42.4	47.9	47.6	38.9	29.1	20.3	11.5	28.9
	NORMAL DRY BULB	30	33.5	39.2	44.8	50.3	57.9	66.2	72.9	72.0	63.1	52.4	41.5	34.3	52.3
	MEAN DRY BULB	50	32.7	38.5	44.2	50.6	58.1	65.6	72.8	71.5	63.5	52.3	41.2	34.6	52.1
	MEAN WET BULB	14	31.3	33.6	39.6	44.4	49.3	53.4	56.5	55.8	51.4	44.4	37.2	27.7	43.7
	MEAN DEW POINT	14	27.5	28.8	33.0	36.4	40.6	42.8	43.3	42.4	40.1	35.9	32.5	24.5	35.7
	NORMAL NO. DAYS WITH:														
	MAXIMUM ≥ 90°	30	0.0	0.0	0.0	*	0.8	5.3	14.4	11.7	2.6	0.1	0.0	0.0	34.9
	MAXIMUM ≤ 32°	30	8.6	2.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	8.1	21.7
	MINIMUM ≤ 32°	30	20.1	14.5	8.8	3.2	0.1	0.0	0.0	0.0	0.2	3.1	10.8	19.7	80.5
	MINIMUM ≤ 0°	30	1.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.2	3.1
H/C	NORMAL HEATING DEG. DAYS	30	977	722	626	441	226	71	15	23	145	391	705	952	5294
	NORMAL COOLING DEG. DAYS	30	0	0	0	0	6	107	260	240	88	0	0	0	701
RH	NORMAL (PERCENT)	30	77	73	63	58	52	46	36	38	47	59	74	78	58
	HOUR 04 LST	30	79	78	73	71	68	63	53	53	61	70	78	80	69
	HOUR 10 LST	30	77	71	60	52	47	41	33	36	42	54	72	78	55
	HOUR 16 LST	30	73	63	49	42	37	31	23	26	32	44	68	76	47
	HOUR 22 LST	30	79	76	68	62	56	49	37	40	51	64	77	80	62
S	PERCENT POSSIBLE SUNSHINE														
W/O	MEAN NO. DAYS WITH:														
	HEAVY FOG(VISBY≤1/4 MI)	60	7.4	4.9	1.9	0.3	0.2	0.1	0.0	0.0	0.2	1.0	6.0	8.5	30.5
	THUNDERSTORMS	60	0.0	0.0	0.2	0.9	1.8	1.9	1.9	2.0	1.1	0.3	0.1	0.0	10.2
CLOUDINESS	MEAN:														
	SUNRISE-SUNSET (OKTAS)	1					6.4				3.2				
	MIDNIGHT-MIDNIGHT (OKTAS)	1										3.2			
	MEAN NO. DAYS WITH:														
	CLEAR	1	1.0	3.0	4.0		5.0	7.0							
	PARTLY CLOUDY	1		3.0	2.0		5.0	3.0							
	CLOUDY	1	3.0	2.0	9.0		10.0	3.0							
PR	MEAN STATION PRESSURE(IN)	24	28.53	28.48	28.40	28.42	28.40	28.39	28.40	28.39	28.44	28.49	28.48	28.54	28.45
	MEAN SEA-LEVEL PRES. (IN)	14	30.16	30.13	30.04	30.01	29.97	29.96	29.96	29.95	29.99	30.06	30.10	30.19	30.04
WINDS	MEAN SPEED (MPH)	33	7.3	7.8	8.8	9.5	9.2	9.1	8.8	8.4	8.0	7.4	7.7	7.4	8.3
	PREVAIL.DIR(TENS OF DEGS)	19	16	15	26	26	26	26	27	27	14	14	16	16	26
	MAXIMUM 2-MINUTE:														
	SPEED (MPH)	2	40	47	55	48	43	32	33	43	33	40	34	41	55
	DIR. (TENS OF DEGS)		29	25	25	25	24	26	26	23	25	25	23	23	25
	YEAR OF OCCURRENCE		1997	1997	1997	1997	1996	1997	1996	1997	1997	1996	1996	1996	MAR 1997
	MAXIMUM 5-SECOND:														
	SPEED (MPH)	2	47	57	63	53	51	40	39	59	40	49	48	48	63
	DIR. (TENS OF DEGS)		27	25	25	25	24	23	25	23	16	24	16	23	25
	YEAR OF OCCURRENCE		1996	1997	1997	1997	1996	1997	1996	1997	1997	1996	1996	1996	MAR 1997
PRECIPITATION	NORMAL (IN)	30	1.51	1.14	1.16	1.04	0.99	0.64	0.35	0.53	0.59	0.86	1.58	1.63	12.02
	MAXIMUM MONTHLY (IN)	62	3.92	3.03	2.82	2.78	3.18	2.70	1.45	2.58	2.34	2.79	3.76	4.68	4.68
	YEAR OF OCCURRENCE		1970	1940	1983	1978	1991	1947	1993	1977	1941	1947	1973	1973	DEC 1973
	MINIMUM MONTHLY (IN)	62	0.21	0.07	0.24	0.01	0.03	0.03	T	0.00	T	T	0.04	0.21	0.00
	YEAR OF OCCURRENCE		1949	1964	1941	1956	1964	1986	1967	1969	1993	1987	1939	1989	AUG 1969
	MAXIMUM IN 24 HOURS (IN)	62	1.29	1.41	1.33	1.24	1.52	1.49	1.19	2.19	1.23	1.88	1.35	1.25	2.19
	YEAR OF OCCURRENCE		1956	1994	1983	1990	1972	1947	1948	1993	1981	1982	1971	1978	AUG 1993
	NORMAL NO. DAYS WITH:														
	PRECIPITATION ≥ 0.01	30	12.0	10.9	10.6	8.7	7.2	5.8	2.9	3.6	4.7	6.1	11.7	12.2	96.4
	PRECIPITATION ≥ 1.00	30	*	0.0	*	0.1	*	0.0	0.0	*	*	*	*	*	0.1
SNOWFALL	NORMAL (IN)	30	6.1	2.1	1.0	0.1	T	0.0	0.0	0.0	0.0	0.2	2.2	5.2	16.9
	MAXIMUM MONTHLY (IN)	61	41.6	16.8	4.9	2.2	T	T	T	0.0	0.0	3.2	14.9	26.6	41.6
	YEAR OF OCCURRENCE		1950	1994	1971	1975	1993	1994	1993			1973	1985	1983	JAN 1950
	MAXIMUM IN 24 HOURS (IN)	61	13.3	16.1	4.0	2.2	T	T	T	0.0	0.0	3.2	8.0	9.9	16.1
	YEAR OF OCCURRENCE		1950	1994	1970	1975	1993	1994	1993			1973	1977	1948	FEB 1994
	MAXIMUM SNOW DEPTH (IN)	49	16	12	6	0	0	0	0	0	0	2	8	11	16
	YEAR OF OCCURRENCE		1957	1994	1993							1971	1978	1985	JAN 1957
	NORMAL NO. DAYS WITH:														
	SNOWFALL ≥ 1.0	30	2.2	0.6	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.6	1.9	5.9

published by: NCDC Asheville, NC

NORMALS, MEANS, AND EXTREMES

SPOKANE, WA (GEG)

LATITUDE:	LONGITUDE:	ELEVATION (FT):		TIME ZONE:	WBAN: 24157
47° 37' 17" N	117° 31' 40" W	GRND: 2357	BARO: 2360	PACIFIC (UTC+ 8)	

	ELEMENT	POR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F	NORMAL DAILY MAXIMUM	30	33.2	40.6	47.7	57.0	65.8	74.7	83.1	82.5	72.0	58.6	41.4	33.8	57.5
	MEAN DAILY MAXIMUM	50	31.8	39.0	47.3	57.0	66.4	74.1	83.2	82.1	72.5	58.2	41.5	33.2	57.2
	HIGHEST DAILY MAXIMUM	50	59	63	71	90	96	101	103	108	98	86	67	56	108
	YEAR OF OCCURRENCE		1971	1995	1960	1977	1986	1992	1967	1961	1988	1997	1975	1980	AUG 1961
	MEAN OF EXTREME MAXS.	50	45.9	51.5	61.5	73.4	84.2	90.2	96.5	95.8	88.6	75.2	55.6	47.5	72.2
	NORMAL DAILY MINIMUM	30	20.8	25.9	29.6	34.7	41.9	49.2	54.4	54.3	45.8	36.0	28.8	21.7	36.9
	MEAN DAILY MINIMUM	50	20.4	25.2	29.5	35.2	42.7	49.4	54.8	54.3	46.3	36.5	28.6	22.4	37.1
	LOWEST DAILY MINIMUM	50	-22	-24	-7	17	24	33	37	35	24	10	-21	-25	-25
	YEAR OF OCCURRENCE		1979	1996	1989	1966	1954	1984	1981	1965	1985	1991	1985	1968	DEC 1968
	MEAN OF EXTREME MINS.	50	-.4	7.0	15.9	25.7	31.2	38.9	44.4	43.6	33.7	24.0	13.5	2.2	23.3
	NORMAL DRY BULB	30	27.1	33.3	38.7	45.9	53.9	62.0	68.8	68.4	58.9	47.3	35.1	27.8	47.3
	MEAN DRY BULB	50	26.1	32.0	38.4	46.1	54.5	61.8	69.0	68.2	59.5	47.4	35.1	27.8	47.2
	MEAN WET BULB	13	27.1	29.2	35.6	41.1	47.2	52.1	55.6	50.7	49.3	41.2	32.8	25.9	40.6
	MEAN DEW POINT	13	24.8	25.4	29.9	33.7	39.0	43.3	44.7	40.3	40.0	34.7	30.1	23.7	34.1
	NORMAL NO. DAYS WITH:														
	MAXIMUM ≥ 90°	30	0.0	0.0	0.0	*	0.3	2.1	8.4	7.2	1.0	0.0	0.0	0.0	19.0
	MAXIMUM ≤ 32°	30	14.2	4.6	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.1	4.1	13.8	37.7
	MINIMUM ≤ 32°	30	26.5	22.4	20.8	10.7	1.7	0.0	0.0	0.0	0.8	9.5	19.9	26.6	138.9
	MINIMUM ≤ 0°	30	2.3	0.5	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.1	5.2
H/C	NORMAL HEATING DEG. DAYS	30	1175	888	815	573	344	139	30	56	223	549	897	1153	6842
	NORMAL COOLING DEG. DAYS	30	0	0	0	0	0	49	148	161	40	0	0	0	398
RH	NORMAL (PERCENT)	30	82	79	70	61	58	54	44	45	54	67	83	86	65
	HOUR 04 LST	30	85	84	81	77	76	74	64	63	71	79	87	87	77
	HOUR 10 LST	30	83	80	69	57	53	49	41	43	51	66	83	86	63
	HOUR 16 LST	30	78	69	55	44	41	36	27	28	35	49	76	82	52
	HOUR 22 LST	30	84	81	74	65	63	58	45	46	56	70	85	87	68
S	PERCENT POSSIBLE SUNSHINE	47	28	41	55	61	65	67	80	78	72	55	29	23	54
W/O	MEAN NO. DAYS WITH:														
	HEAVY FOG(VISBY≤1/4 MI)	50	9.4	7.1	3.1	1.2	0.8	0.5	0.2	0.3	0.8	4.0	8.6	8.6	44.6
	THUNDERSTORMS	50	0.0	0.0	0.3	0.7	1.6	2.8	2.4	2.1	0.8	0.3	0.1	0.0	11.1
CLOUDINESS	MEAN:														
	SUNRISE-SUNSET (OKTAS)	1			7.2										
	MIDNIGHT-MIDNIGHT (OKTAS)														
	MEAN NO. DAYS WITH:														
	CLEAR	1		2.0	3.0		3.0	6.0							
	PARTLY CLOUDY	1		3.0	2.0		3.0	1.0							
	CLOUDY	1	4.0	3.0	10.0		10.0	4.0							
PR	MEAN STATION PRESSURE(IN)	23	27.58	27.55	27.47	27.49	27.48	27.49	27.52	27.51	27.55	27.58	27.54	27.58	27.53
	MEAN SEA-LEVEL PRES. (IN)	13	30.15	30.12	30.02	29.98	29.94	29.94	29.96	29.95	30.00	30.05	30.08	30.15	30.03
WINDS	MEAN SPEED (MPH)	35	8.5	9.1	9.7	10.1	9.3	9.3	8.7	8.2	8.1	8.1	8.7	8.3	8.8
	PREVAIL.DIR(TENS OF DEGS)	15	05	06	22	22	22	22	22	22	22	22	05	05	22
	MAXIMUM 2-MINUTE:														
	SPEED (MPH)	2	37	34	41	46	44	29	34	31	32	38	28	32	46
	DIR. (TENS OF DEGS)		18	22	25	25	26	26	26	25	21	22	24	22	25
	YEAR OF OCCURRENCE		1997	1996	1997	1997	1997	1996	1996	1996	1997	1997	1997	1997	APR 1997
	MAXIMUM 5-SECOND:														
	SPEED (MPH)	2	43	41	47	53	48	34	40	39	38	45	32	40	53
	DIR. (TENS OF DEGS)		20	21	25	26	26	23	26	27	20	23	22	22	26
	YEAR OF OCCURRENCE		1997	1996	1997	1997	1997	1997	1996	1996	1997	1997	1997	1997	APR 1997
PRECIPITATION	NORMAL (IN)	30	1.98	1.49	1.49	1.18	1.41	1.26	0.67	0.72	0.73	0.99	2.15	2.42	16.49
	MAXIMUM MONTHLY (IN)	50	4.96	3.94	3.81	3.08	5.71	3.06	2.33	1.83	2.05	4.05	5.10	5.13	5.71
	YEAR OF OCCURRENCE		1959	1961	1995	1948	1948	1964	1990	1976	1959	1950	1973	1964	MAY 1948
	MINIMUM MONTHLY (IN)	50	0.38	0.35	0.31	0.08	0.20	0.16	T	T	T	0.03	0.22	0.60	T
	YEAR OF OCCURRENCE		1985	1988	1965	1956	1982	1960	1994	1988	1990	1987	1976	1976	JUL 1994
	MAXIMUM IN 24 HOURS (IN)	50	1.48	1.11	1.08	1.41	1.67	2.07	1.80	1.09	1.12	1.23	1.41	1.60	2.07
	YEAR OF OCCURRENCE		1954	1963	1995	1997	1948	1964	1990	1959	1973	1994	1960	1951	JUN 1964
	NORMAL NO. DAYS WITH:														
	PRECIPITATION ≥ 0.01	30	13.1	10.8	11.1	8.9	9.2	7.7	4.5	5.1	5.7	7.1	12.8	14.7	110.7
	PRECIPITATION ≥ 1.00	30	*	0.0	0.0	0.0	0.0	0.1	*	0.0	*	0.0	*	0.1	0.2
SNOWFALL	NORMAL (IN)	30	14.2	6.7	3.6	0.9	0.2	0.0	0.0	0.0	0.0	0.3	6.4	15.1	47.4
	MAXIMUM MONTHLY (IN)	49	56.9	28.5	15.3	6.6	3.5	T	0.0	0.0	T	6.1	24.7	42.0	56.9
	YEAR OF OCCURRENCE		1950	1975	1962	1964	1967	1994			1991	1957	1955	1964	JAN 1950
	MAXIMUM IN 24 HOURS (IN)	49	13.0	11.0	6.1	4.9	3.5	T	0.0	0.0	T	6.1	9.0	12.1	13.0
	YEAR OF OCCURRENCE		1950	1993	1989	1964	1967	1994			1991	1957	1973	1951	JAN 1950
	MAXIMUM SNOW DEPTH (IN)	48	39	42	16	2	0	0	0	0	0	4	12	23	42
	YEAR OF OCCURRENCE		1969	1969	1969	1990						1957	1985	1951	FEB 1969
	NORMAL NO. DAYS WITH:														
	SNOWFALL ≥ 1.0	30	4.7	2.5	1.4	0.3	0.*	0.0	0.0	0.0	0.0	0.1	2.1	5.0	16.1

NORMALS, MEANS, AND EXTREMES

YAKIMA, WA (YKM)

LATITUDE: 46° 33' 51" N | LONGITUDE: 120° 32' 01" W | ELEVATION (FT): GRND: 1052 BARO: 1068 | TIME ZONE: PACIFIC (UTC+ 8) | WBAN: 24243

	ELEMENT	POR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F	NORMAL DAILY MAXIMUM	30	37.5	46.4	55.2	63.2	71.6	79.5	86.7	85.7	76.8	64.4	48.3	37.5	62.8
	MEAN DAILY MAXIMUM	50	37.1	45.6	55.2	63.7	72.6	79.8	87.4	85.9	77.6	64.3	48.1	37.9	62.9
	HIGHEST DAILY MAXIMUM	51	68	69	80	92	102	105	108	110	100	88	73	67	110
	YEAR OF OCCURRENCE		1977	1947	1960	1977	1986	1992	1971	1971	1988	1992	1989	1980	AUG 1971
	MEAN OF EXTREME MAXS.	50	54.0	59.5	68.0	78.3	89.0	94.4	99.9	98.5	90.8	78.0	62.8	54.6	77.3
	NORMAL DAILY MINIMUM	30	21.8	26.4	30.8	35.5	42.3	49.2	53.1	52.3	44.6	35.3	29.0	22.1	36.9
	MEAN DAILY MINIMUM	50	20.3	25.5	29.9	34.9	42.1	49.0	52.8	51.6	44.1	34.8	27.9	22.3	36.3
	LOWEST DAILY MINIMUM	51	-21	-25	-1	20	25	30	34	35	24	11	-13	-17	-25
	YEAR OF OCCURRENCE		1950	1950	1960	1985	1954	1984	1971	1960	1985	1971	1985	1964	FEB 1950
	MEAN OF EXTREME MINS.	50	1.8	9.3	19.1	24.5	29.5	36.8	41.1	41.2	32.9	23.0	14.7	6.0	23.3
	NORMAL DRY BULB	30	29.7	36.4	43.0	49.4	57.0	64.6	69.9	69.0	60.7	49.9	38.6	29.8	49.8
	MEAN DRY BULB	50	28.7	35.5	42.5	49.3	57.4	64.4	70.2	68.8	60.8	49.6	38.0	30.2	49.6
	MEAN WET BULB	14	28.4	31.8	38.5	43.5	49.4	54.2	58.6	53.7	52.2	43.3	31.6	26.4	42.6
	MEAN DEW POINT	14	23.3	24.9	28.5	34.2	39.6	44.0	48.0	44.5	43.9	36.6	27.5	23.5	34.9
	NORMAL NO. DAYS WITH:														
	MAXIMUM ≥ 90°	30	0.0	0.0	0.0	*	1.0	5.0	13.1	10.9	1.7	0.0	0.0	0.0	31.7
	MAXIMUM ≤ 32°	30	9.8	2.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	8.9	22.2
	MINIMUM ≤ 32°	30	27.3	23.0	19.7	11.5	2.8	0.2	0.0	0.0	1.1	11.2	20.6	27.5	144.9
	MINIMUM ≤ 0°	30	1.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.3	3.4
H/C	NORMAL HEATING DEG. DAYS	30	1094	801	682	468	255	90	19	38	169	468	792	1091	5967
	NORMAL COOLING DEG. DAYS	30	0	0	0	0	7	78	171	162	40	0	0	0	458
RH	NORMAL (PERCENT)	30	78	73	61	52	48	47	44	48	56	63	74	80	60
	HOUR 04 LST	30	82	82	76	71	70	69	67	70	75	79	82	84	76
	HOUR 10 LST	30	78	71	55	43	39	38	36	40	45	55	73	80	54
	HOUR 16 LST	30	70	57	40	33	31	30	26	28	32	41	62	74	44
	HOUR 22 LST	30	81	78	67	58	55	53	51	55	64	72	80	82	66
S	PERCENT POSSIBLE SUNSHINE														
W/O	MEAN NO. DAYS WITH:														
	HEAVY FOG(VISBY≤1/4 MI)	51	4.8	2.4	0.6	0.1	0.1	0.0	0.0	0.0	0.1	0.7	3.5	6.8	19.1
	THUNDERSTORMS	51	0.0	0.0	0.1	0.4	1.1	1.7	1.4	1.3	0.6	0.1	0.0	0.0	6.7
CLOUDINESS	MEAN:														
	SUNRISE-SUNSET (OKTAS)	50	6.3	5.9	5.4	5.2	4.7	4.2	2.5	2.7	3.1	4.5	5.8	6.2	4.7
	MIDNIGHT-MIDNIGHT (OKTAS)	29	5.9	5.3	4.7	4.6	4.1	3.8	2.4	2.5	2.8	3.9	5.4	5.8	4.3
	MEAN NO. DAYS WITH:														
	CLEAR	50	4.0	4.4	6.2	6.2	8.4	10.3	18.7	17.5	15.0	9.5	5.1	4.0	109.3
	PARTLY CLOUDY	50	5.4	5.8	8.3	9.4	10.5	9.8	8.0	7.8	7.9	8.3	6.0	5.2	92.4
	CLOUDY	50	21.6	18.0	16.6	14.4	12.1	9.9	4.3	5.6	7.1	13.2	18.9	21.8	163.5
PR	MEAN STATION PRESSURE(IN)	22	29.00	28.93	28.85	28.86	28.83	28.83	28.83	28.82	28.87	28.93	28.94	29.00	28.89
	MEAN SEA-LEVEL PRES. (IN)	14	30.18	30.13	30.04	30.00	29.95	29.95	29.95	29.94	29.99	30.07	30.09	30.19	30.04
WINDS	MEAN SPEED (MPH)	42	5.6	6.4	7.9	8.5	8.4	8.2	8.0	7.6	7.4	6.7	5.9	5.2	7.1
	PREVAIL.DIR(TENS OF DEGS)	18	27	27	27	27	27	26	27	27	27	28	27	26	27
	MAXIMUM 2-MINUTE:														
	SPEED (MPH)	1	31	31	33	40	28	30	25	34	31	31	26	26	40
	DIR. (TENS OF DEGS)		02	28	25	30	28	27	31	27	20	21	31	19	30
	YEAR OF OCCURRENCE		1997	1997	1997	1997	1997	1997	1997	1997	1997	1997	1997	1997	APR 1997
	MAXIMUM 5-SECOND:														
	SPEED (MPH)	1	40	37	43	51	32	36	31	41	41	41	33	32	51
	DIR. (TENS OF DEGS)		22	28	19	30	19	26	30	27	20	21	30	19	30
	YEAR OF OCCURRENCE		1997	1997	1997	1997	1997	1997	1997	1997	1997	1997	1997	1997	APR 1997
PRECIPITATION	NORMAL (IN)	30	1.21	0.74	0.67	0.50	0.45	0.53	0.16	0.40	0.40	0.47	1.03	1.41	7.97
	MAXIMUM MONTHLY (IN)	51	3.68	2.46	2.63	1.83	2.76	2.53	0.71	2.10	2.07	2.22	2.83	5.59	5.59
	YEAR OF OCCURRENCE		1995	1961	1957	1995	1948	1991	1966	1975	1986	1950	1973	1996	DEC 1996
	MINIMUM MONTHLY (IN)	51	0.09	T	0.01	T	0.03	0.01	T	0.00	0.00	0.00	T	0.07	0.00
	YEAR OF OCCURRENCE		1985	1988	1973	1985	1964	1970	1988	1955	1986	1978	1990	1976	SEP 1986
	MAXIMUM IN 24 HOURS (IN)	51	1.37	0.87	0.74	1.25	0.90	1.56	0.66	1.74	1.49	1.05	2.03	1.58	2.03
	YEAR OF OCCURRENCE		1963	1961	1987	1974	1986	1982	1963	1990	1986	1982	1996	1977	NOV 1996
	NORMAL NO. DAYS WITH:														
	PRECIPITATION ≥ 0.01	30	8.8	6.9	6.5	4.6	5.0	4.3	2.1	2.9	3.4	4.1	8.5	10.0	67.1
	PRECIPITATION ≥ 1.00	30	0.1	0.0	0.0	*	0.0	*	0.0	0.1	*	*	*	0.1	0.3
SNOWFALL	NORMAL (IN)	30	7.7	2.7	1.3	T	T	0.0	0.0	0.0	0.0	0.1	2.2	9.5	23.5
	MAXIMUM MONTHLY (IN)	51	26.6	16.5	10.8	0.2	T	0.0	0.0	0.0	0.0	2.9	23.5	37.5	37.5
	YEAR OF OCCURRENCE		1950	1949	1971	1993	1994					1991	1996	1964	DEC 1964
	MAXIMUM IN 24 HOURS (IN)	51	13.6	8.2	7.4	0.2	T	0.0	0.0	0.0	0.0	2.4	18.9	14.0	18.9
	YEAR OF OCCURRENCE		1963	1994	1951	1993	1994					1991	1996	1964	NOV 1996
	MAXIMUM SNOW DEPTH (IN)	49	21	15	7	0	0	0	0	0	0	2	9	19	21
	YEAR OF OCCURRENCE		1997	1969	1969							1991	1984	1964	JAN 1997
	NORMAL NO. DAYS WITH:														
	SNOWFALL ≥ 1.0	30	2.4	1.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.6	3.0	7.6

NORMALS, MEANS, AND EXTREMES

PENDLETON, OREGON

LATITUDE: 45°41'N LONGITUDE: 118°51'W ELEVATION: FT. GRND 1462 BARO 1507 TIME ZONE: PACIFIC WBAN: 24155

	(a)	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F:														
Normals														
-Daily Maximum		39.4	46.9	53.4	61.4	70.6	79.6	88.9	85.9	77.1	63.7	48.7	42.5	63.2
-Daily Minimum		26.3	31.8	34.4	39.2	46.1	52.9	58.6	57.5	50.5	41.3	33.4	29.5	41.8
-Monthly		32.8	39.4	43.9	50.3	58.4	66.2	73.8	71.7	63.8	52.5	41.1	36.0	52.5
Extremes														
-Record Highest	55	68	72	79	91	100	108	110	113	102	92	77	67	113
-Year		1974	1986	1964	1977	1986	1961	1939	1961	1955	1980	1975	1980	AUG 1961
-Record Lowest	55	-22	-18	10	18	25	36	42	40	30	11	-12	-19	-22
-Year		1957	1950	1955	1936	1954	1966	1971	1980	1970	1935	1985	1983	JAN 1957
NORMAL DEGREE DAYS:														
Heating (base 65°F)		998	717	654	441	220	75	7	27	120	388	717	899	5263
Cooling (base 65°F)		0	0	0	0	16	111	280	235	84	0	0	0	726
% OF POSSIBLE SUNSHINE														
MEAN SKY COVER (tenths)														
Sunrise - Sunset	45	8.4	8.0	7.3	6.8	6.1	5.4	3.0	3.4	4.1	5.8	7.9	8.4	6.2
MEAN NUMBER OF DAYS:														
Sunrise to Sunset														
-Clear	55	2.4	2.7	4.8	5.4	7.5	9.7	19.5	18.0	15.0	10.1	3.5	2.6	101.2
-Partly Cloudy	55	5.2	5.6	7.5	9.4	10.7	10.1	7.6	7.8	7.8	7.9	6.5	4.6	90.8
-Cloudy	55	23.4	19.9	18.6	15.2	12.9	10.1	3.9	5.2	7.2	13.0	20.0	23.8	173.2
Precipitation														
.01 inches or more	55	12.4	10.7	10.8	8.8	7.8	6.5	2.6	3.1	4.4	7.1	11.3	12.6	98.3
Snow, Ice pellets														
1.0 inches or more	55	2.7	1.1	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.*	0.5	1.4	6.1
Thunderstorms	53	0.0	0.*	0.2	0.8	1.8	1.9	1.8	2.0	1.1	0.3	0.1	0.*	10.0
Heavy Fog Visibility														
1/4 mile or less	53	7.2	4.7	1.7	0.3	0.2	0.1	0.0	0.*	0.2	1.0	6.0	8.6	30.2
Temperature °F														
-Maximum														
90° and above	55	0.0	0.0	0.0	0.*	0.8	4.6	14.4	10.6	2.7	0.*	0.0	0.0	33.1
32° and below	55	9.3	2.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	7.4	21.8
-Minimum														
32° and below	55	21.2	15.8	9.5	2.5	0.1	0.0	0.0	0.0	0.1	2.5	12.3	19.3	83.4
0° and below	55	1.7	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.7	3.1
AVG. STATION PRESS.(mb)	17	966.2	964.7	961.7	962.5	961.9	961.6	961.8	961.3	962.9	964.9	964.1	966.7	963.4
RELATIVE HUMIDITY (%)														
Hour 04	49	80	79	73	71	69	65	54	54	62	72	79	82	70
Hour 10 (Local Time)	51	77	71	59	51	47	42	34	37	43	55	72	76	56
Hour 16	51	75	65	49	42	37	32	23	26	32	47	69	76	48
Hour 22	48	80	77	69	63	58	52	38	41	51	66	78	81	63
PRECIPITATION (inches):														
Water Equivalent														
-Normal		1.73	1.11	1.06	0.99	1.09	0.70	0.30	0.55	0.58	0.95	1.48	1.66	12.20
-Maximum Monthly	55	3.92	3.03	2.82	2.78	3.02	2.70	1.26	2.58	2.34	2.79	3.76	4.68	4.68
-Year		1970	1940	1983	1978	1962	1947	1948	1977	1941	1947	1973	1973	DEC 1973
-Minimum Monthly	55	0.21	0.07	0.24	0.01	0.03	0.03	T	0.00	T	T	0.04	0.21	0.00
-Year		1949	1964	1941	1956	1964	1986	1967	1969	1990	1987	1939	1985	AUG 1969
-Maximum in 24 hrs	55	1.29	1.09	1.33	1.24	1.52	1.49	1.19	1.48	1.23	1.88	1.35	1.25	1.88
-Year		1956	1959	1983	1990	1972	1947	1948	1977	1981	1982	1971	1976	OCT 1982
Snow, Ice pellets														
-Maximum Monthly	55	41.6	15.8	4.9	2.2	T	0.0	0.0	0.0	0.0	3.2	14.9	26.6	41.6
-Year		1950	1936	1971	1975	1989					1973	1985	1983	JAN 1950
-Maximum in 24 hrs	55	13.3	9.7	4.0	2.2	T	0.0	0.0	0.0	0.0	3.2	8.0	9.9	13.3
-Year		1950	1949	1970	1975	1989					1973	1977	1946	JAN 1950
WIND:														
Mean Speed (mph)	37	7.9	8.4	9.4	9.9	9.6	9.7	9.0	8.6	8.4	7.7	7.8	7.8	8.7
Prevailing Direction through 1963		SE	SE	W	W	W	W	WNW	SE	SE	SE	SE	SE	SE
Fastest Obs. 1 Min.														
-Direction (!!!)	35	23	25	29	27	27	29	28	27	27	25	27	29	27
-Speed (MPH)	35	49	54	63	77	48	62	46	40	47	49	62	63	77
-Year		1990	1955	1956	1960	1959	1956	1968	1961	1954	1959	1959	1959	APR 1960
Peak Gust														
-Direction (!!!)	7	SW	SW	W	SW	W	W	W	W	W	W	W	W	SW
-Speed (mph)	7	76	52	63	61	60	49	62	55	56	47	58	62	76
-Date		1990	1988	1984	1987	1988	1986	1990	1990	1984	1985	1989	1990	JAN 1990

(!!!) See Reference Notes on Page 68.

NORMALS, MEANS, AND EXTREMES

SPOKANE WASHINGTON

LATITUDE: 47°38'N LONGITUDE: 117°32'W ELEVATION: FT. GRND 2357 BARO 2360 TIME ZONE: PACIFIC WBAN: 24157

	(a)	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F:														
Normals														
-Daily Maximum		31.3	39.0	46.2	56.7	66.1	74.0	84.0	81.7	72.4	58.3	41.4	34.2	57.1
-Daily Minimum		20.0	25.7	29.0	34.9	42.5	49.3	55.3	54.3	46.5	36.7	28.5	23.7	37.2
-Monthly		25.7	32.4	37.6	45.8	54.3	61.7	69.7	68.1	59.4	47.6	34.9	29.0	47.2
Extremes														
-Record Highest	43	59	61	71	90	96	100	103	108	98	86	67	56	108
-Year		1971	1958	1960	1977	1986	1973	1967	1961	1988	1980	1975	1980	AUG 1961
-Record Lowest	43	-22	-17	-7	17	24	33	37	35	24	11	-21	-25	-25
-Year		1979	1979	1989	1966	1954	1984	1981	1965	1985	1984	1985	1968	DEC 1968
NORMAL DEGREE DAYS:														
Heating (base 65°F)		1218	913	849	576	339	140	17	63	209	539	903	1116	6882
Cooling (base 65°F)		0	0	0	0	8	41	162	159	41	0	0	0	411
% OF POSSIBLE SUNSHINE	42	27	40	54	61	63	66	80	77	71	55	28	22	54
MEAN SKY COVER (tenths)														
Sunrise - Sunset	43	8.3	8.0	7.4	7.1	6.7	6.1	3.8	4.2	4.8	6.3	8.1	8.4	6.6
MEAN NUMBER OF DAYS:														
Sunrise to Sunset														
-Clear	43	3.0	3.3	4.2	4.5	5.5	7.3	16.5	15.2	12.3	8.0	3.2	2.8	85.7
-Partly Cloudy	43	4.3	5.0	7.8	8.3	10.1	10.3	8.3	8.4	8.1	7.7	5.0	3.9	87.4
-Cloudy	43	23.7	20.0	19.0	17.2	15.4	12.4	6.1	7.4	9.6	15.3	21.8	24.3	192.1
Precipitation .01 inches or more	43	14.2	11.4	11.5	8.6	9.4	7.7	4.3	5.0	5.7	7.6	12.6	15.0	112.9
Snow, Ice pellets 1.0 inches or more	43	5.3	2.9	1.6	0.2	0.*	0.0	0.0	0.0	0.0	0.1	2.0	5.0	17.2
Thunderstorms	43	0.*	0.*	0.3	0.7	1.6	2.9	2.1	2.1	0.7	0.3	0.1	0.0	10.7
Heavy Fog Visibility 1/4 mile or less	43	9.4	7.2	3.0	1.2	0.9	0.4	0.2	0.3	0.8	4.2	8.5	12.2	48.3
Temperature °F														
-Maximum														
90° and above	31	0.0	0.0	0.0	0.*	0.3	2.0	8.8	7.2	1.0	0.0	0.0	0.0	19.2
32° and below	31	14.5	4.6	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	4.0	14.0	38.1
-Minimum														
32° and below	31	26.6	22.7	20.7	10.7	1.7	0.0	0.0	0.0	0.8	9.5	20.0	26.6	139.3
0° and below	31	2.5	0.5	0.*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.0	5.3
AVG. STATION PRESS. (mb)	17	934.0	932.9	930.0	931.1	930.6	931.0	931.8	931.4	932.7	933.9	932.3	934.4	932.2
RELATIVE HUMIDITY (%)														
Hour 04	31	85	84	81	77	77	74	64	63	71	79	87	87	77
Hour 10 (Local Time)	31	83	80	69	57	53	49	40	43	51	66	83	86	63
Hour 16	31	78	69	55	44	41	36	27	28	34	49	76	83	52
Hour 22	31	84	81	74	65	63	58	45	46	56	70	85	87	68
PRECIPITATION (inches):														
Water Equivalent														
-Normal		2.47	1.61	1.36	1.08	1.38	1.23	0.50	0.74	0.71	1.08	2.06	2.49	16.71
-Maximum Monthly	43	4.96	3.94	3.75	3.08	5.71	3.06	2.33	1.83	2.05	4.05	5.10	5.13	5.71
-Year		1959	1961	1950	1948	1948	1964	1990	1976	1959	1950	1973	1964	MAY 1948
-Minimum Monthly	43	0.38	0.35	0.31	0.08	0.20	0.16	T	T	T	0.03	0.22	0.60	T
-Year		1985	1988	1965	1956	1982	1960	1973	1988	1990	1987	1976	1976	SEP 1990
-Maximum in 24 hrs	43	1.48	1.11	0.96	1.01	1.67	2.07	1.80	1.09	1.12	0.98	1.41	1.60	2.07
-Year		1954	1963	1989	1982	1948	1964	1990	1959	1973	1955	1960	1951	JUN 1964
Snow, Ice pellets														
-Maximum Monthly	43	56.9	28.5	15.3	6.6	3.5	T	0.0	0.0	0.0	6.1	24.7	42.0	56.9
-Year		1950	1975	1962	1964	1967	1954				1957	1955	1964	JAN 1950
-Maximum in 24 hrs	43	13.0	8.9	6.1	4.9	3.5	T	0.0	0.0	0.0	6.1	9.0	12.1	13.0
-Year		1950	1975	1989	1964	1967	1954				1957	1973	1951	JAN 1950
WIND:														
Mean Speed (mph)	43	8.8	9.3	9.7	10.0	9.2	9.2	8.6	8.2	8.3	8.2	8.7	8.6	8.9
Prevailing Direction through 1963		NE	SSW	SSW	SW	SSW	SSW	SW	SW	NE	SSW	NE	NE	SSW
Fastest Mile														
-Direction (!!)	43	SW	SW	SW	SW	W	SW	SW	SW	SW	SW	SW	SW	SW
-Speed (MPH)	43	59	54	54	52	49	44	43	50	38	56	54	51	59
-Year		1972	1949	1971	1987	1957	1986	1970	1982	1961	1950	1949	1956	JAN 1972
Peak Gust														
-Direction (!!)	7	SW	S	W	SW	W	SW	SW	NW	SW	SE	SW	NE	SW
-Speed (mph)	7	56	51	52	62	53	49	51	47	47	49	56	51	62
-Date		1986	1987	1988	1987	1986	1989	1989	1984	1987	1985	1990	1990	APR 1987

(!!) See Reference Notes on Page 6B.

NORMALS, MEANS, AND EXTREMES

YAKIMA WASHINGTON

LATITUDE: 46°34'N   LONGITUDE: 120°32'W   ELEVATION: FT. GRND 1052 BARO 1068   TIME ZONE: PACIFIC   WBAN: 24243

	(a)	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F:														
Normals														
-Daily Maximum		36.7	46.0	54.5	63.5	72.5	79.9	87.8	85.6	77.5	64.5	48.1	39.4	63.0
-Daily Minimum		19.7	26.1	29.2	34.7	42.1	49.1	53.0	51.5	44.3	35.1	28.2	23.6	36.4
-Monthly		28.2	36.1	41.9	49.2	57.3	64.5	70.4	68.6	60.9	49.9	38.2	31.5	49.7
Extremes														
-Record Highest	44	68	69	80	92	102	103	108	110	100	87	73	67	110
-Year		1977	1947	1960	1977	1986	1961	1971	1971	1988	1988	1989	1980	AUG 1971
-Record Lowest	44	-21	-25	-1	20	25	30	34	35	24	11	-13	-17	-25
-Year		1950	1950	1960	1985	1954	1984	1971	1960	1985	1971	1985	1964	FEB 1950
NORMAL DEGREE DAYS:														
Heating (base 65°F)		1141	809	716	474	254	101	18	46	161	468	804	1039	6031
Cooling (base 65°F)		0	0	0	0	16	86	186	158	38	0	0	0	484
% OF POSSIBLE SUNSHINE														
MEAN SKY COVER (tenths)														
Sunrise - Sunset	44	7.9	7.4	6.8	6.5	5.9	5.3	3.1	3.5	4.1	5.8	7.4	7.9	6.0
MEAN NUMBER OF DAYS:														
Sunrise to Sunset														
-Clear	44	4.2	4.3	6.1	6.2	8.2	10.4	18.9	17.5	14.9	9.4	4.9	4.0	108.9
-Partly Cloudy	44	5.3	6.0	8.3	9.4	10.6	9.7	7.8	7.8	7.8	8.3	6.0	5.3	92.3
-Cloudy	44	21.5	17.9	16.7	14.4	12.2	9.9	4.4	5.7	7.3	13.4	19.0	21.6	164.0
Precipitation .01 inches or more	44	9.4	7.1	6.5	4.5	5.0	4.7	2.0	2.9	3.2	5.0	8.4	9.6	68.5
Snow, Ice pellets 1.0 inches or more	42	2.7	1.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.*	0.7	2.7	7.9
Thunderstorms	44	0.0	0.*	0.1	0.5	1.1	1.7	1.4	1.3	0.6	0.1	0.0	0.0	6.8
Heavy Fog Visibility 1/4 mile or less	44	4.6	2.3	0.5	0.*	0.1	0.0	0.*	0.0	0.1	0.7	3.3	6.9	18.5
Temperature °F														
-Maximum														
90° and above	44	0.0	0.0	0.0	0.*	1.3	4.7	13.7	10.6	2.3	0.0	0.0	0.0	32.6
32° and below	44	10.3	2.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	8.4	22.9
-Minimum														
32° and below	44	28.0	23.8	20.6	11.9	2.8	0.1	0.0	0.0	1.0	10.9	21.2	27.8	148.3
0° and below	44	2.4	0.6	0.*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.9	4.1
AVG. STATION PRESS. (mb)	17	982.1	979.4	976.8	977.4	976.5	976.2	976.3	975.8	977.7	979.7	979.5	982.4	978.3
RELATIVE HUMIDITY (%)														
Hour 04	43	83	82	77	72	70	70	68	71	77	81	84	85	77
Hour 10 (Local Time)	44	78	70	54	41	39	38	36	39	44	55	73	80	54
Hour 16	44	71	58	41	33	31	31	25	28	32	43	63	75	44
Hour 22	42	81	79	69	58	56	54	51	55	65	74	81	83	67
PRECIPITATION (inches):														
Water Equivalent														
-Normal		1.44	0.74	0.65	0.50	0.48	0.60	0.14	0.36	0.33	0.47	0.97	1.30	7.98
-Maximum Monthly	44	3.66	2.46	2.63	1.62	2.76	2.10	0.71	2.10	2.07	2.22	2.83	4.19	4.19
-Year		1970	1961	1957	1963	1948	1948	1966	1975	1986	1950	1973	1964	DEC 1964
-Minimum Monthly	44	0.09	T	0.01	T	0.03	0.01	T	0.00	0.00	0.00	T	0.07	0.00
-Year		1985	1988	1973	1985	1964	1970	1988	1955	1986	1978	1990	1976	SEP 1986
-Maximum in 24 hrs	44	1.37	0.87	0.74	1.25	0.90	1.56	0.66	1.74	1.49	1.05	1.08	1.58	1.74
-Year		1963	1961	1987	1974	1986	1982	1963	1990	1986	1982	1955	1977	AUG 1990
Snow, Ice pellets														
-Maximum Monthly	44	26.6	16.5	10.8	T	T	0.0	0.0	0.0	0.0	2.4	21.2	37.5	37.5
-Year		1950	1949	1971	1983	1986					1973	1955	1964	DEC 1964
-Maximum in 24 hrs	44	13.6	5.8	7.4	T	T	0.0	0.0	0.0	0.0	2.4	11.2	14.0	14.0
-Year		1963	1956	1951	1983	1986					1973	1984	1964	DEC 1964
WIND:														
Mean Speed (mph)	38	5.7	6.4	7.9	8.6	8.5	8.2	7.8	7.4	7.4	6.6	5.9	5.2	7.1
Prevailing Direction through 1963		W	W	W	WNW	WNW	NW	WNW	WNW	WNW	WNW	W	W	WNW
Fastest Obs. 1 Min.														
-Direction (!!!)	36	25	29	23	29	18	20	24	29	20	31	29	23	28
-Speed (MPH)	36	44	48	48	46	46	47	43	35	38	41	45	48	48
-Year		1962	1967	1956	1961	1961	1955	1968	1988	1959	1988	1955	1955	FEB 1967
Peak Gust														
-Direction (!!!)	7	W	W	W	S	NE	SE	SW		W	SW	NW	NW	NE
-Speed (mph)	7	55	56	51	52	69	51	54	43	49	54	58	53	69
-Date		1988	1985	1988	1989	1985	1987	1990	1989	1988	1990	1989	1990	MAY 1985

(!!!) See Reference Notes on Page 6B.

ANNEX B

HIGHWAY WHEAT AND BARLEY FLOWS WITH AND WITHOUT THE SNAKE RIVER WATERWAY

The four figures presented in this Annex show highways used to transport wheat and barley to railroad- or river-port-based grain elevators. Maps of wheat and barley flows are presented for the Existing Condition Pathway (Base Scenario) and the Natural River Drawdown Pathway (No-Barge Scenario). The highways are color coded to indicate the number of bushels transported over eastern Washington roads. Grain volumes can be translated to the number of trucks by assuming that each bushel weighs 60 pounds, and the truck capacity is 26 tons. The maps were originally presented in the publicly funded EWITS Report Number 23 (Jessup, Ellis, and Casavant, 1997), which may be obtained at the website for Washington State Unversity (http://ewits.wsu.edu/frames5.htm).

Figure 8. Optimized Wheat Flows on Eastern Washington Highways (Base Scenario)

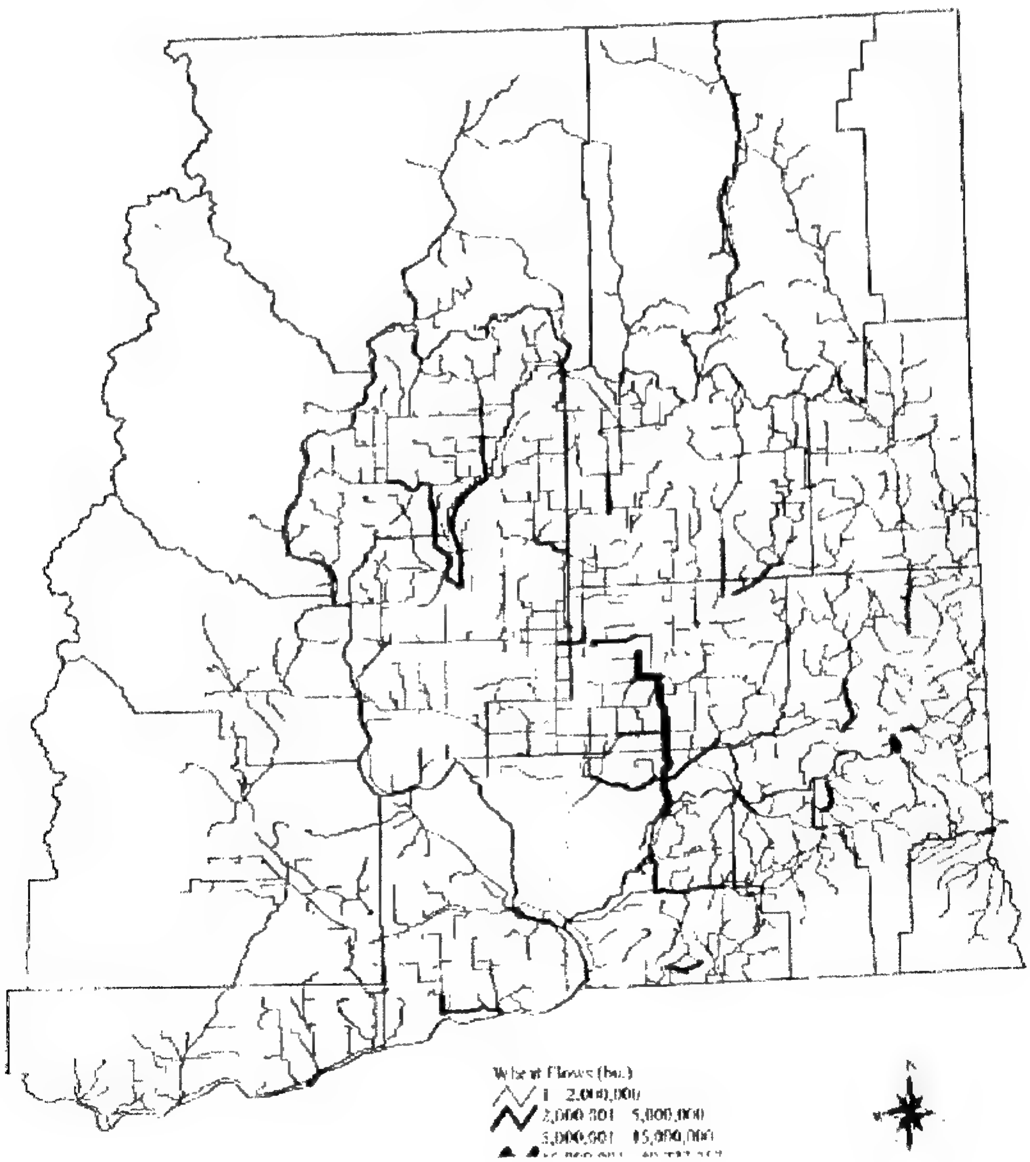

Figure 9. Optimized Wheat Flows on Eastern Washington Highways (No-Barge Scenario)

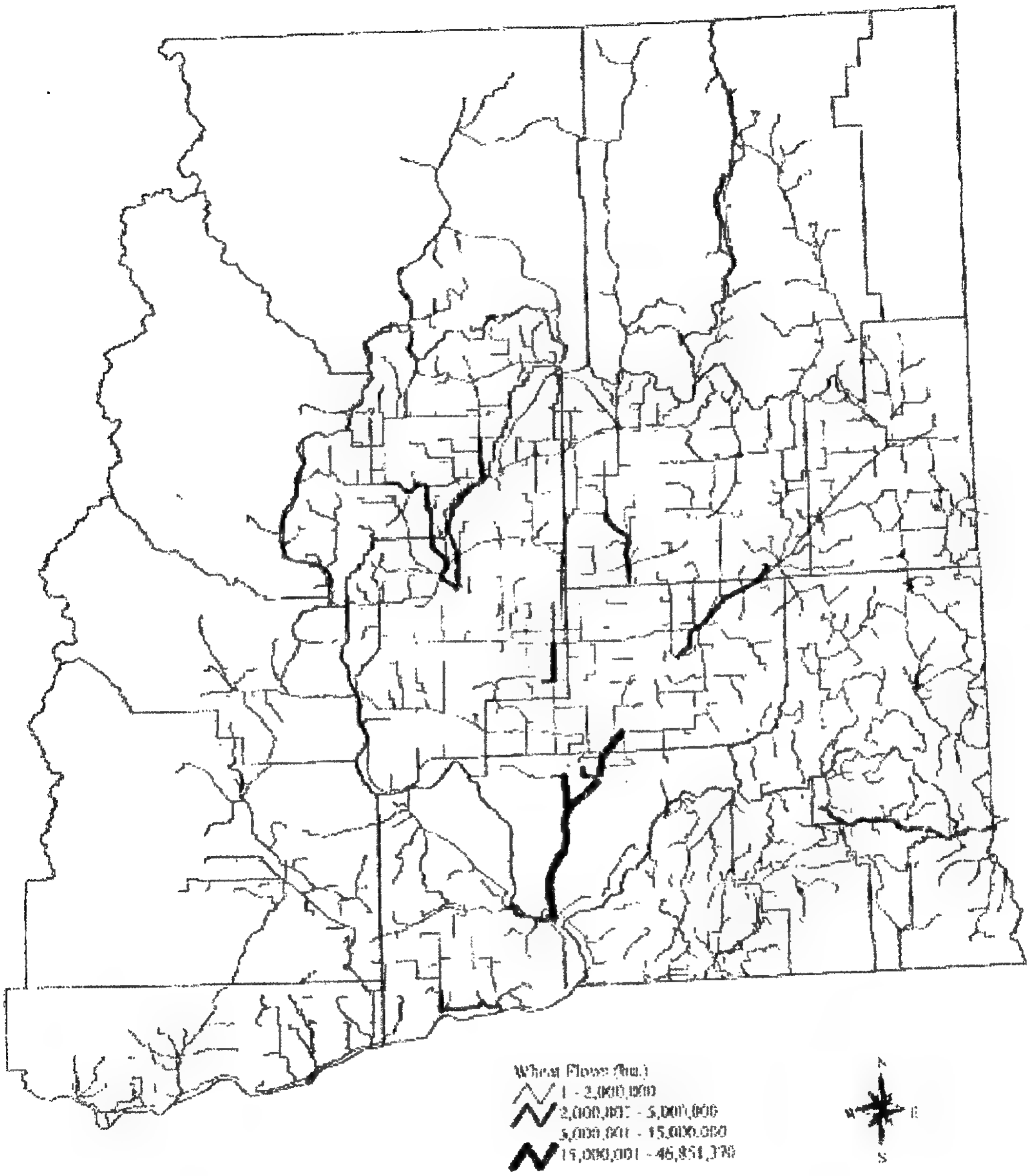

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Figure 10. Optimized Barley Flows on Eastern Washington Highways (Base Scenario)

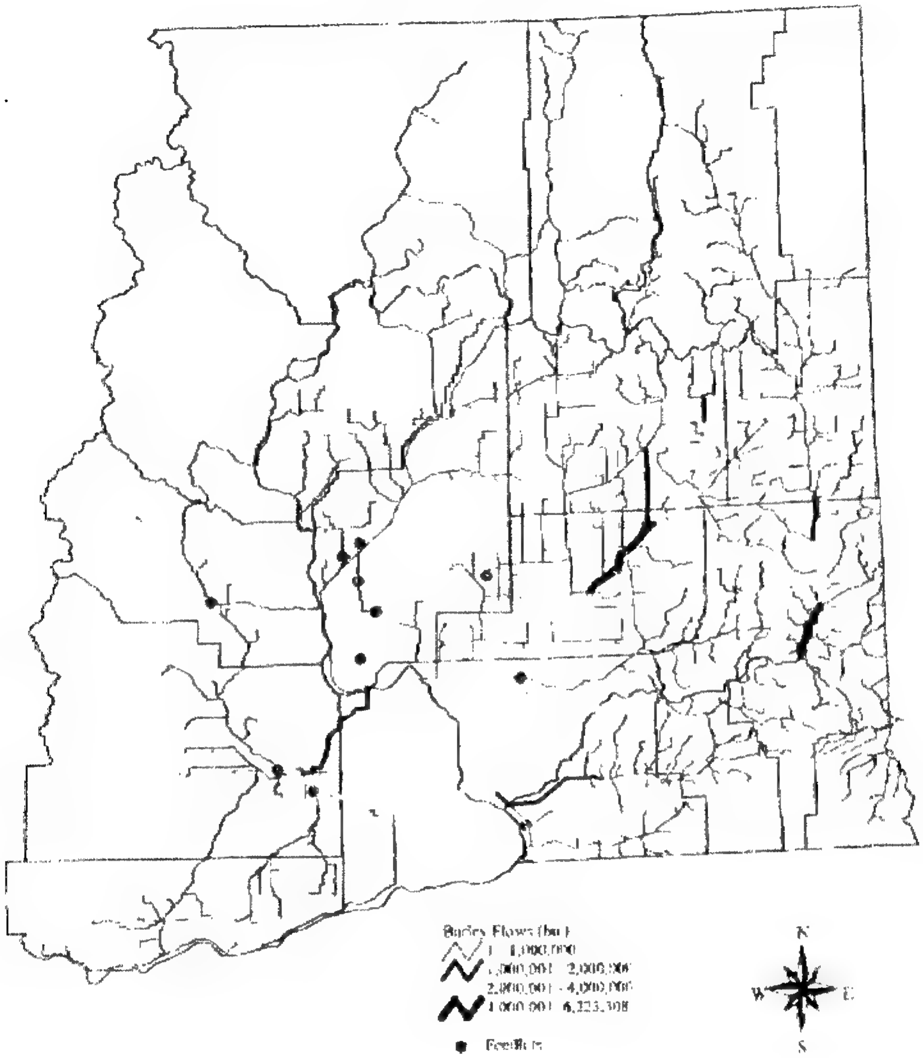
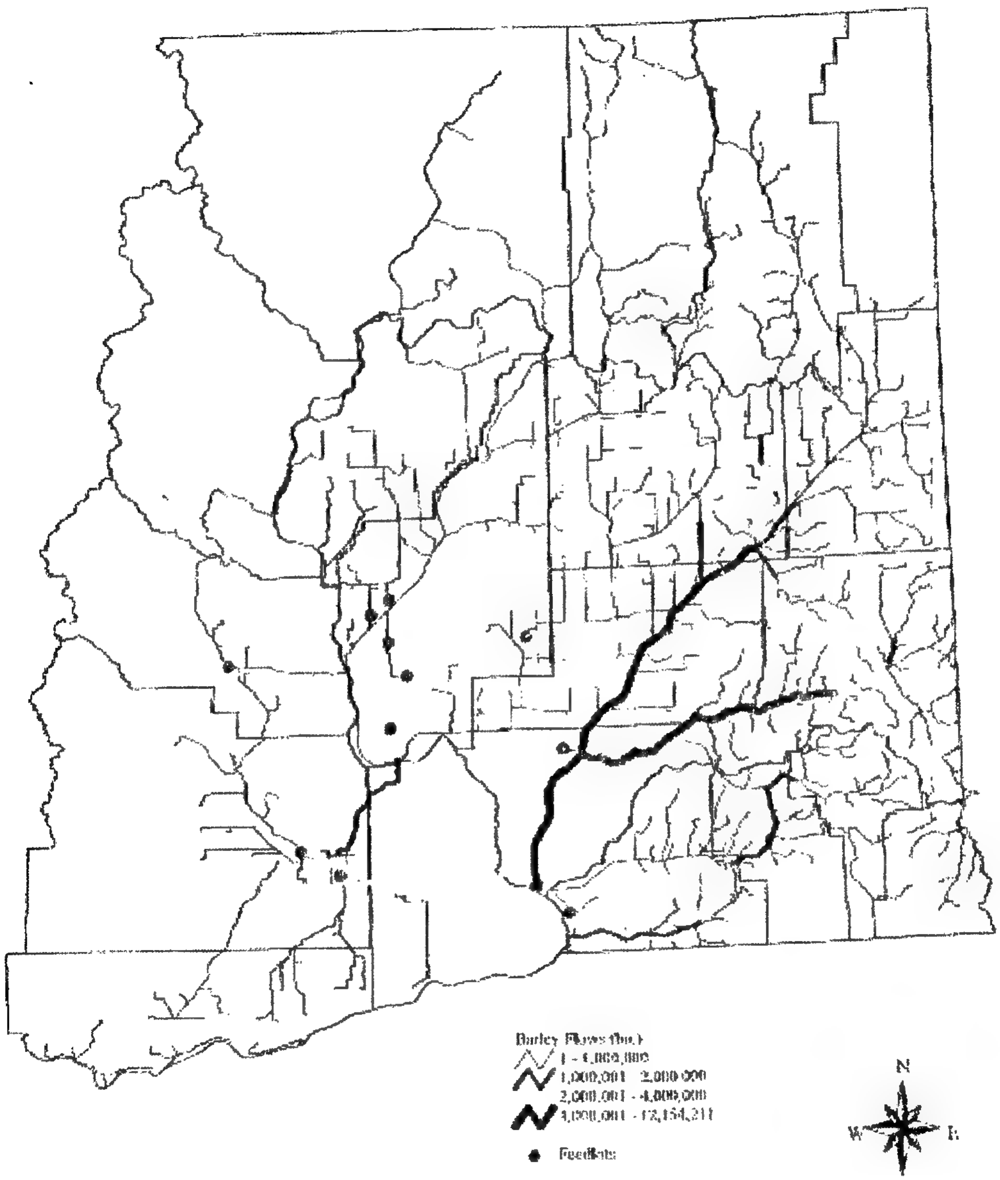


Figure 11. Optimized Barley Flows on Eastern Washington Highways (No-Barge Scenario)



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ANNEX C

PREDICTED PM_{10} CONCENTRATIONS FOR STORM EVENTS

The figures in this Annex show the distribution of predicted 24-hour PM_{10} concentrations for eastern Washington storms. The predictions were developed from CP^3 modeling and were presented in Claiborn et al., 1998. Data used to develop the plots were provided by Brian Lamb, Laboratory for Atmospheric Research, Washington State University, Pullman, Washington. Additional information on the CP^3 program may be obtained at http://coopext.cahe.wsu.edu/ncp3/.

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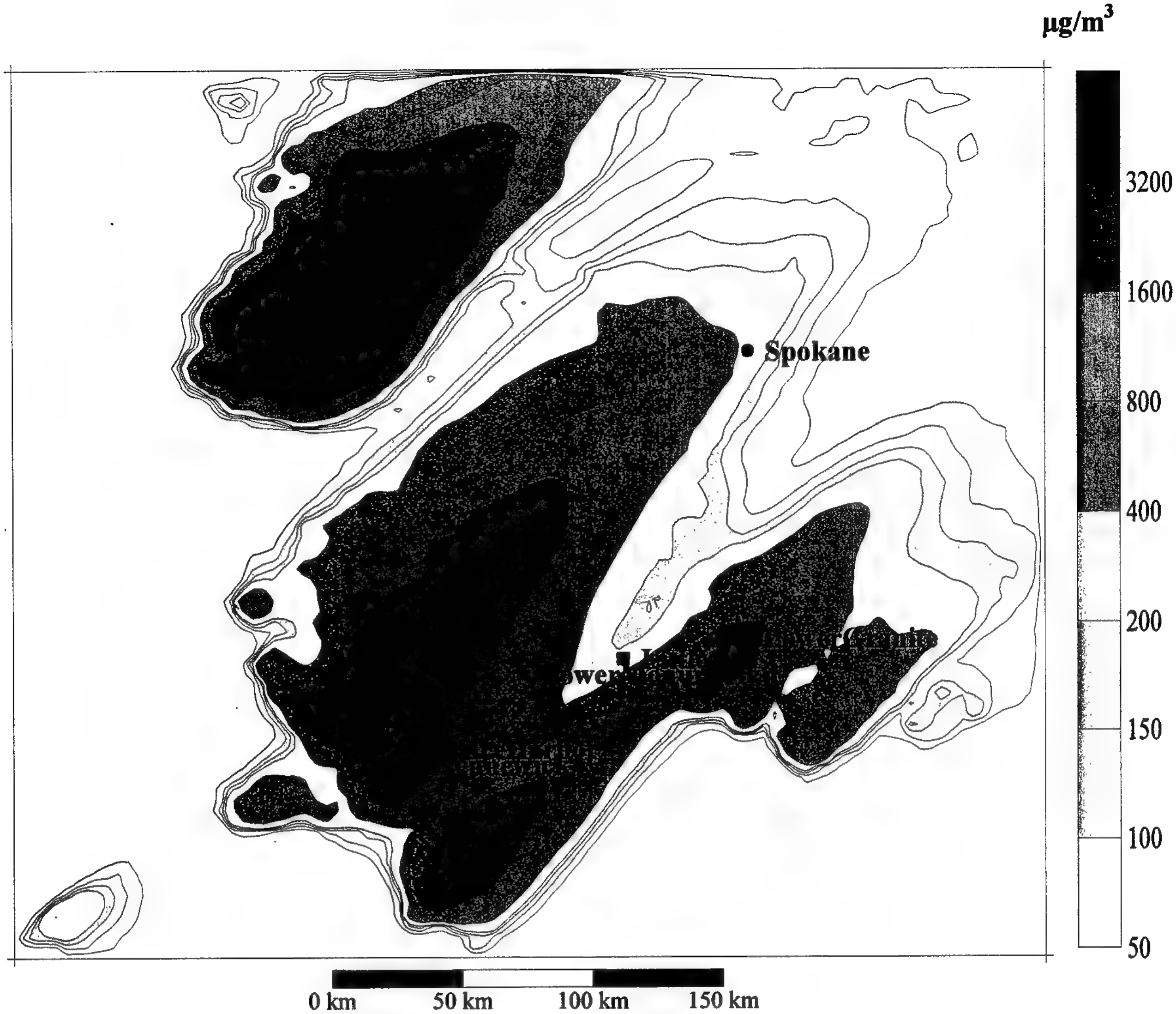
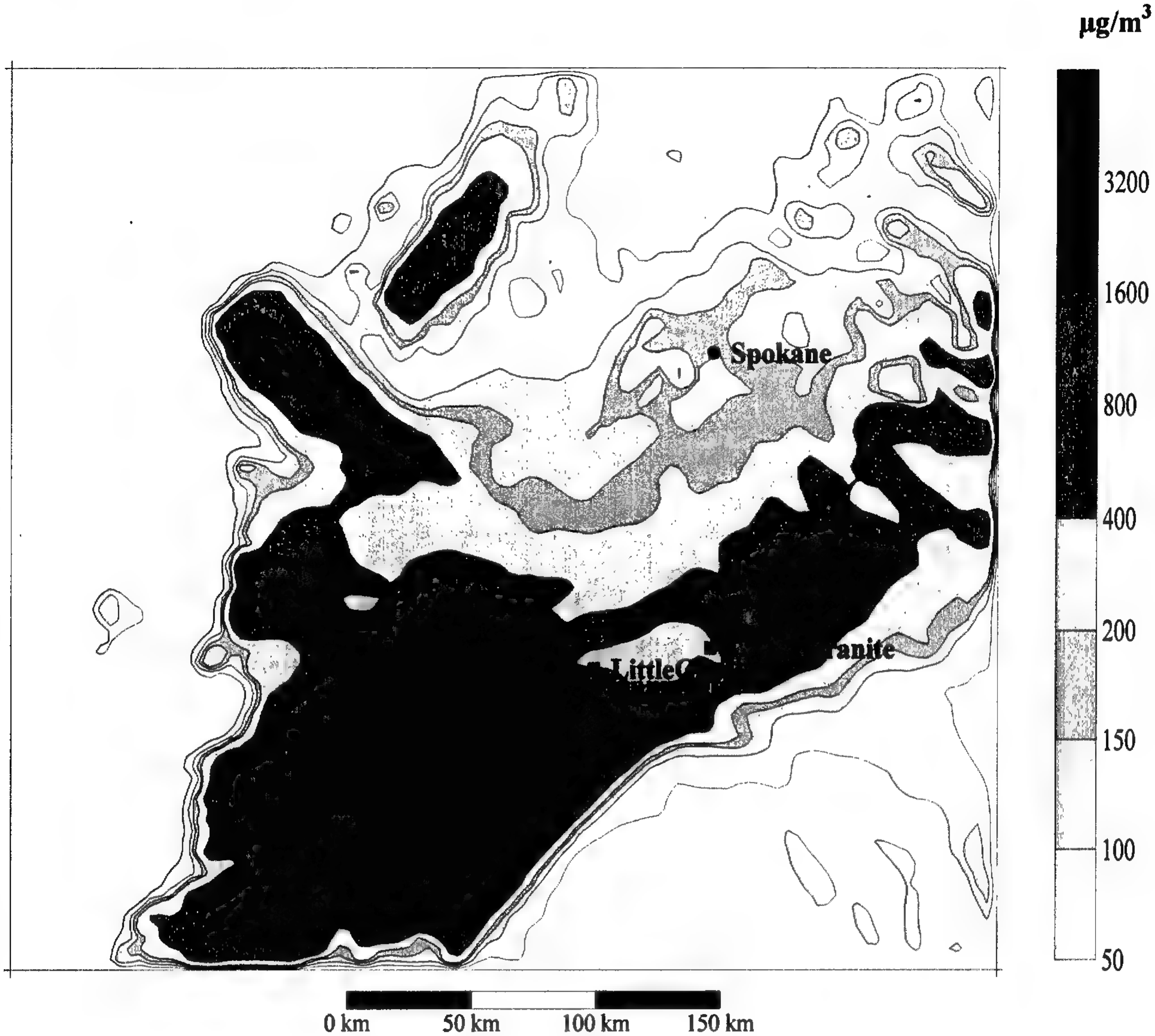
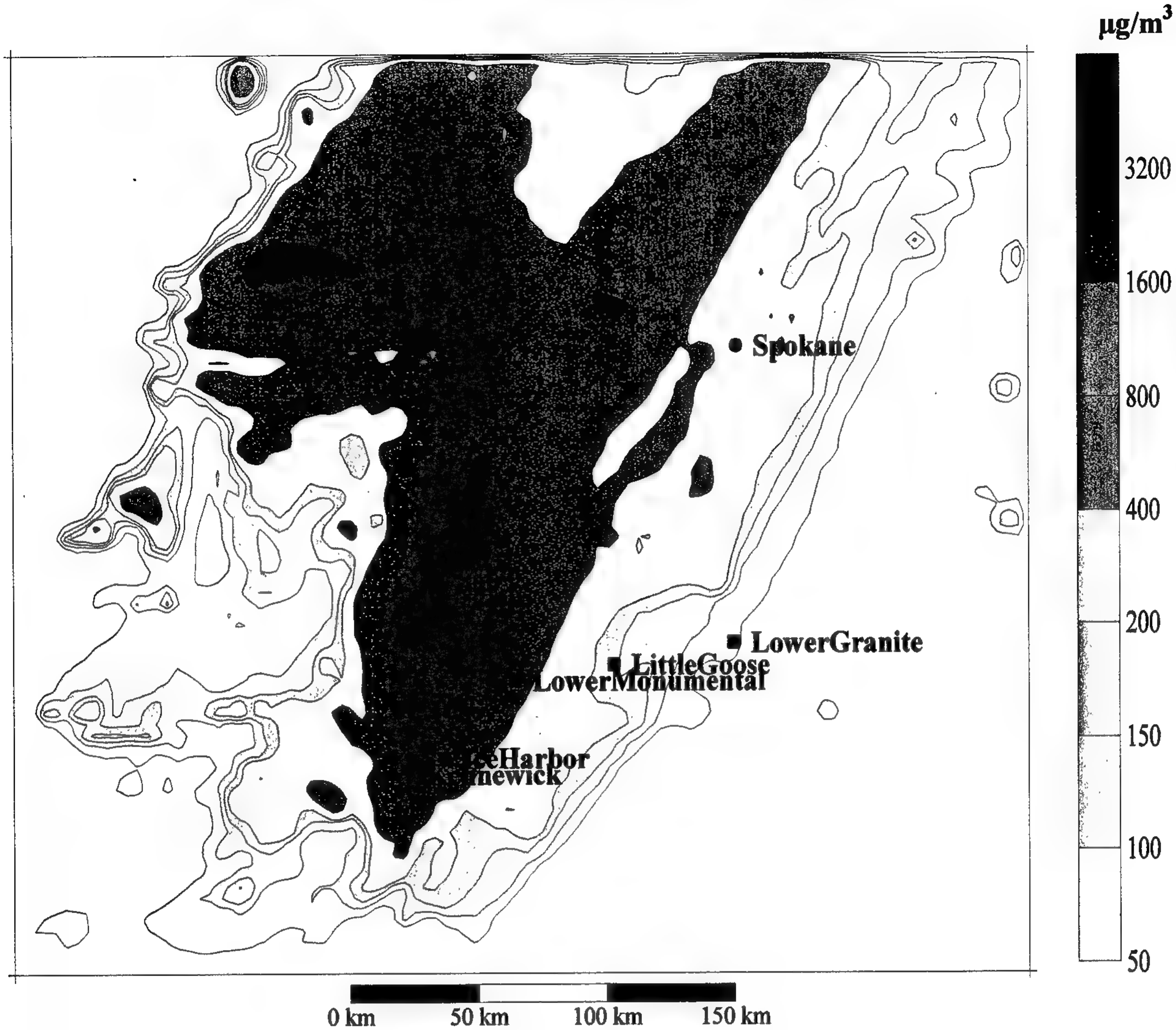
24-Hour Predicted PM_{10} Concentrations for September 11, 1993



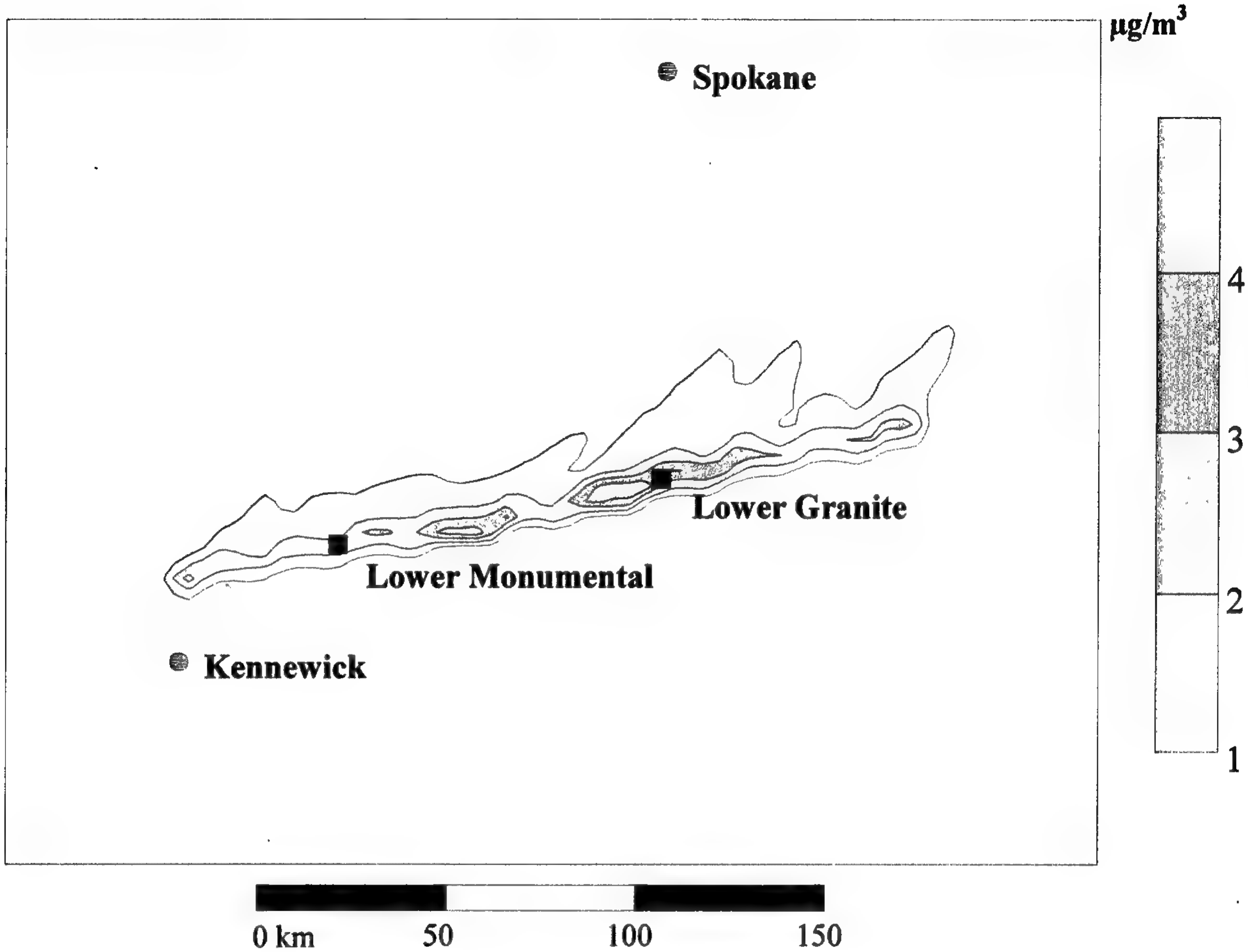
24-Hour Predicted PM_{10} Concentrations for November 3, 1993



24-Hour Predicted PM_{10} Concentrations for November 23, 1990, with the Original Land Use Cover

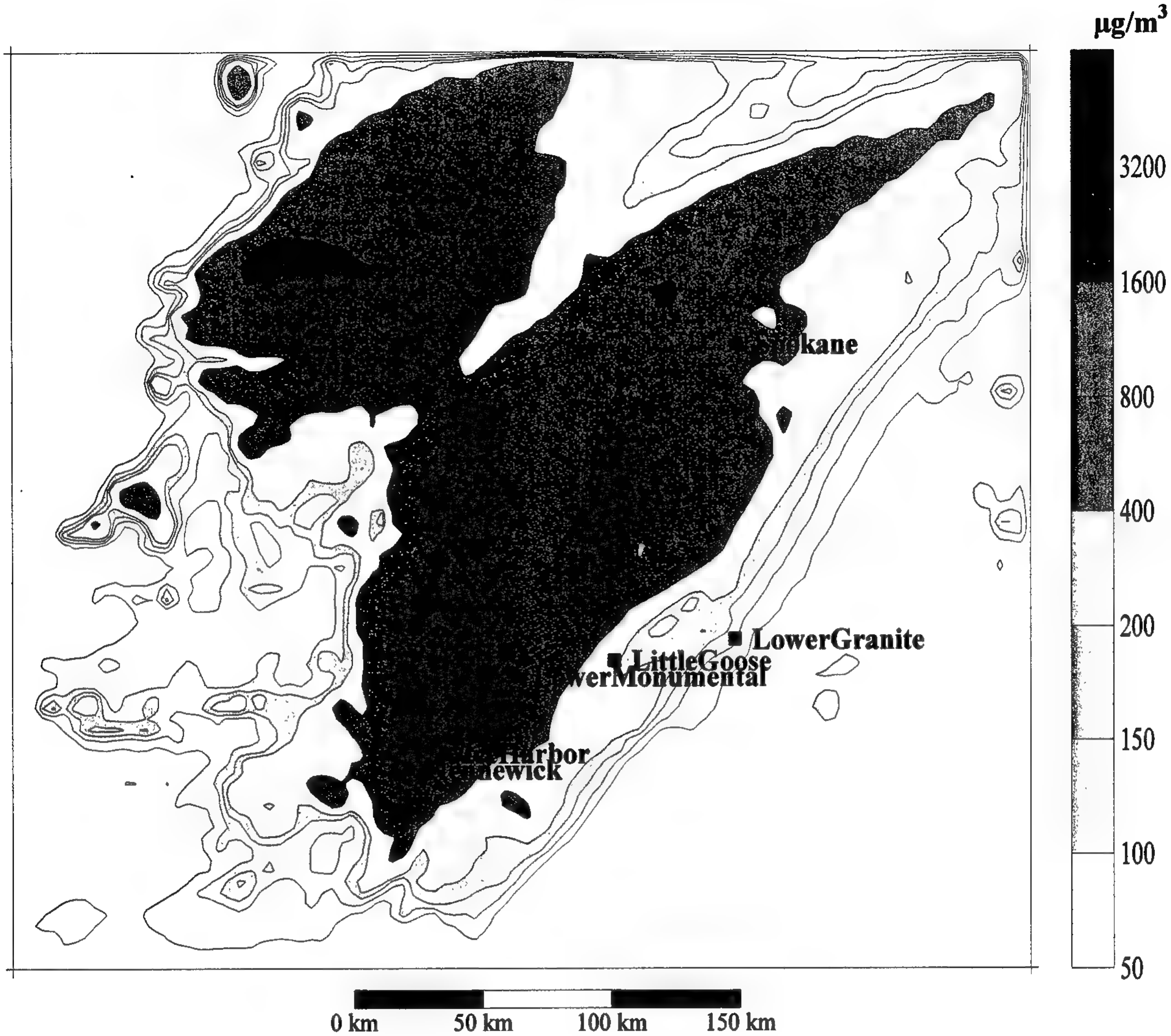


24-Hour Predicted PM_{10} Concentrations for November 23, 1990, for Snake River Reservoir Sediment Emissions



*Not to scale.

24-Hour Predicted PM_{10} Concentrations for November 23, 1990, with the Modified Land Use Cover



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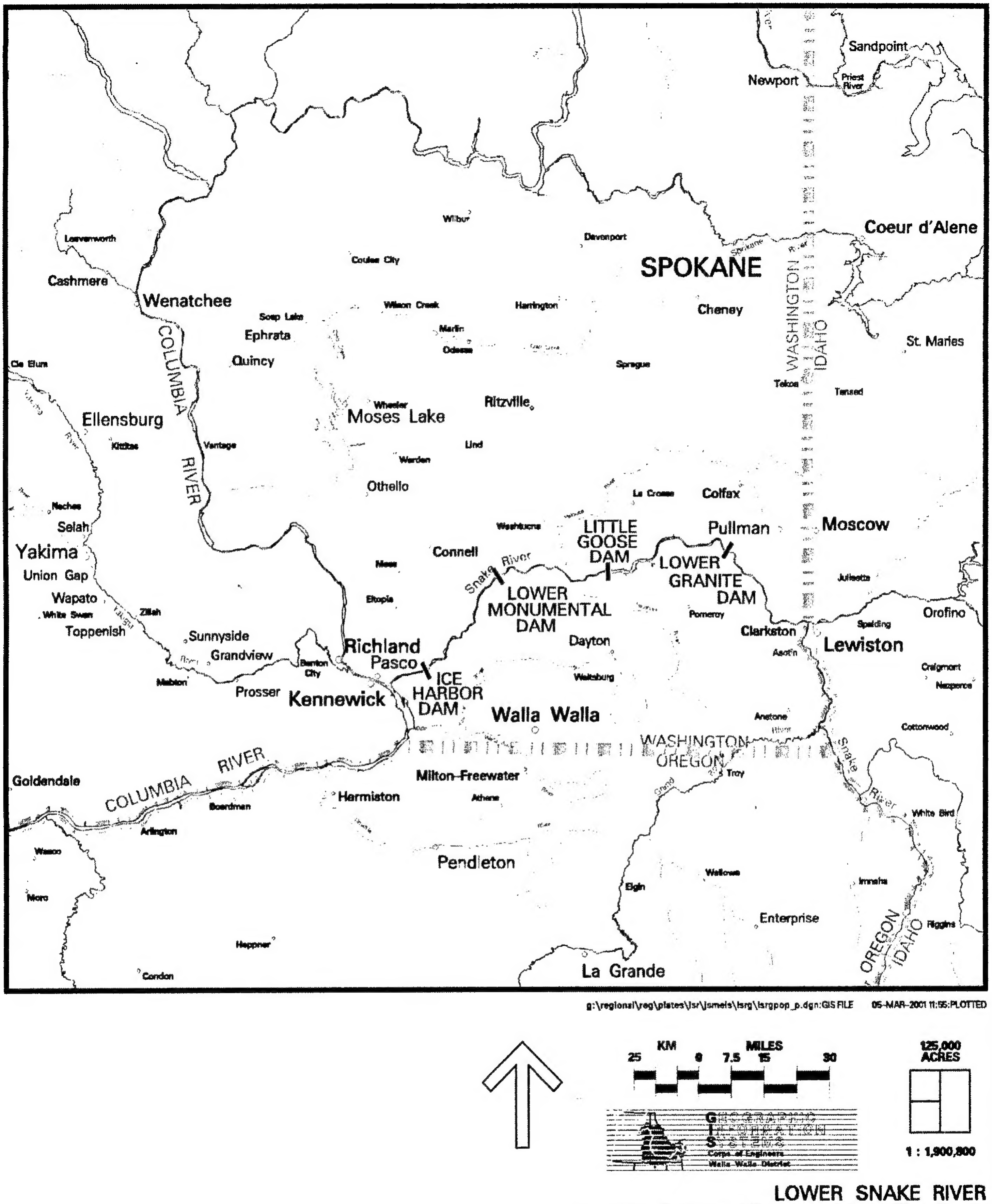
ANNEX D

POPULATION DISTRIBUTION MAP



LOWER SNAKE RIVER
Juvenile Salmon Migration Feasibility Study

Figure 1.
POPULATION CENTERS

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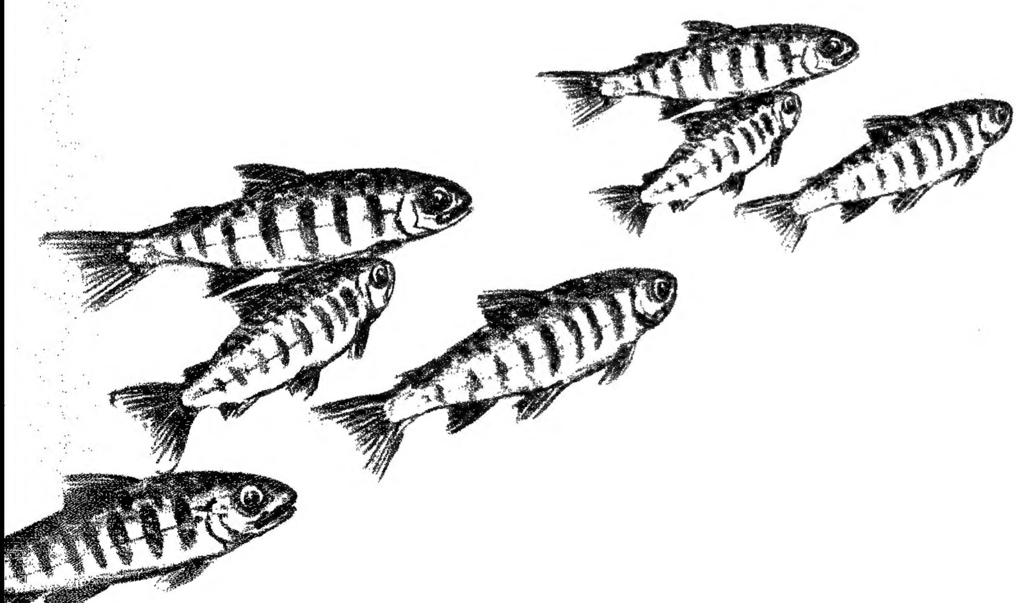
For More Information

Visit the Walla Walla District Home Page
at http://www.nww.usace.army.mil

Department of the Army
Walla Walla District, Corps of Engineers
201 North Third Avenue
Walla Walla, WA 99362-1876



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Bonneville
Power Administration